THE LAY-OUT DESIGN AND CONSTRUCTION OF CHEMICAL AND METALLURGICAL PLANTS

OSKAR NAGEL

THE

LAY-OUT, DESIGN AND CONSTRUCTION

OF

CHEMICAL AND METALLURGICAL PLANTS

DETAILED DESCRIPTIONS AND ILLUSTRATIONS OF ACTUAL LAYOUTS AND CONSTRUCTIONS OF ACID, ALKALI, FERTILIZER, BRICK, CEMENT, GAS, COKE, AND OTHER PLANTS, OF SPELTER AND COPPER WORKS, GOLD AND SILVER MILLS, ETC.

A HAND-BOOK FOR ENGINEERS, CHEMISTS, METALLURGISTS, MANUFACTURERS, SUPERINTENDENTS AND STUDENTS

BY

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PREFACE.

The subject and aim of this book are clearly expressed in the title and therefore the author desires only to make a few remarks about the scope and arrangement of the book.

The subject of "Layout, Design and Construction of Chemical and Metallurgical Plants" has been treated by the author thoroughly and completely. Actual plants and illustrations only were used in the make-up.

After a general discussion of the problems met with and the conditions to be considered in the layout of a factory, the construction of a typical factory building is described, which in the succeeding chapters (spelter, etc.) is further supplemented. The travel of material from start to finish is clearly shown in the chapter on cement plants; the layout of factory railways and the handling of huge quantities of material in the chapter on iron and steel; the use of various appliances in an organic sequence is shown in the chapters on acids, alkali, purification of water, sampling, concentrating, cyaniding, silver refining, etc., while complete layouts are also illustrated in the chapters on copper-, coke-, fertilizer- and peat-plants.

The problem of "proper location" is carefully considered in the chapters on cement, iron and spelter, and the cost of production has not been lost sight of.

It is to be noted that the book should be read as a whole, *i. e.,* as one unit, as one work, for the reason that it was impossible to discuss *all* the important points in *every* chapter. While in one chapter the "building problem" is treated in detail, it will be found that in other chapters other problems and conditions are especially considered.

The book will be of value to chemical and metallurgical engineers, manufacturers and students. It will also be found useful as a text-book on the subject of chemical engineering, since it combines and surveys the details and special branches of this science.

OSKAR NAGEL, PH.D.

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INTRODUCTION.

If a corporation or a business man or an enterprising engineer starts to take the erection of a new plant into consideration, a good many questions have to be answered and a good many preliminary problems have to be solved, before it is definitely decided to really enter into the deal. These considerations involve nothing less than a preconstruction of the future in thought. And this preconstruction will be the more valuable, reliable and authoritative the more care has been devoted to the collection of the data and the more completely the really important circumstances and conditions have been considered. A correct preconstruction means success, a faulty preconstruction means failure. We will therefore discuss, first of all, the important points to be considered in the establishment of a new plant.

Raw Materal.—If the erection of a factory is planned for the exploitation of a chemical process it is to be ascertained if the raw materials at disposal are of suitable quality. In case of a cement plant suitable raw materials have to be at hand in the immediate vicinity of the factory to be erected, while in a sulphuric acid plant the expenses for freight on the pyrites must not go above a certain point. If the insufficiency of the raw material is only found out after the erection of the factory, it is, of course, too late.

Locality.—The next point to be considered is the selection of the proper locality. In this respect many mistakes are made, mistakes which cause a considerable decrease of the profits of the enterprise. The locality has to be of such nature as to allow a convenient extension of the factory in the future. The geologic nature must be such, that the foundations for the buildings may be built at moderate expense. It must not be overlooked to investigate, if a sufficient supply of water can be obtained without extensive and questionable well drilling. And finally it must be ascertained if a sufficient supply of satisfactory labor can be had without insurmountable difficulties.

Preliminary Estimate.—When the above questions are favorably settled, a preliminary estimate of the cost of the plant and the proba-

ble profits is made. Though the actual value of such a preliminary estimate is, to a large extent, problematic, as it can give not more than a rough approximation to the actual results, it is to be prepared with greatest care under consideration of all accessible facts, as otherwise it is absolutely unreliable and without value.

Layout.—A preliminary layout is now made up and changed until it seems to be satisfactory. The machinery must be so arranged that there is plenty of room for the operators. The material to be handled should not travel back and forth. It is always advisable to have the raw material enter at one end of the plant and the finished product leave at the other. Great attention has to be paid to the location and arrangement of transporting devices, such as conveyors, elevators, hoists and pumps. The location of the power plant is naturally of paramount importance; in nearly all cases a central location of this part of the plant will be advisable, in order to facilitate the equal distribution of power.

Working Drawings.—The preparation of the detailed drawings represents the next step. At this stage of the work the exact construction of the various machines, apparatus and appliances has to be decided upon, also the kind of power and construction of the prime mover and the construction of the factory buildings. Local conditions play a large part in the determination of these details. With cheap water power at hand a water wheel or water turbine will be adapted, according to the nature of the waterfall. With cheap coals steam power will have to be used while with expensive coals gas power will be advisable, except in works where the heat of the exhaust steam can be fully utilized. In deciding upon the construction of the building the local conditions are also of importance. In some cases and under certain conditions the construction of frame buildings will be advisable, in others steel construction, in others concrete or corrugated steel walls. The construction to be selected is to a large extent determined by the product to be manufactured and by the prevailing insurance rates.

Specifications.—When everything has developed so far, the specifications are drawn up for the buildings and machines. Every detail as regards the raw materials for buildings and appliances must be carefully considered in the specifications, so that by the combination of the latter with the detailed drawings each and every part of the installation is fully and exactly determined.

Finally contracts are made with the most satisfactory bidders—satisfactory does in this case not mean "cheapest"—the erection is superintended in order to make sure that the specifications are actually followed by the contractor and, as the last stage of the transaction, the installation is formally accepted. Before the final acceptance each and every part of the installation has to be tested as to its capacity, strength or other qualities, which are of importance for the performance and execution of the manufacturing process.

CHAPTER I.

FACTORY CONSTRUCTION.

A manufacturer about to build a factory or warehouse must choose between several types of construction. In this selection the governing considerations are cost, safety, durability and fire protection, while many minor factors enter into each individual case.

In this chapter the qualities of the different materials available for factories are discussed with special reference to the reinforced concrete.

Types of buildings for mills, factories and warehouses may be classified as follows:

1. Frame construction.
2. Steel construction.
3. Mill or slow burning construction.
4. Reinforced concrete construction.

The first and cheapest type of frame construction may be neglected as unsuitable for permanent installation because of its lack of durability and its fire risk. Broad walls, narrow floor joists, board floors and roofs not only do not protect against fire, but in themselves afford fuel even when the contents of a factory are not combustible.

Steel construction with concrete or tile floors, provided the steel is itself protected from fire by concrete or tile, is efficient and durable, but its first cost alone will usually prohibit its use for the ordinary factory building.

Mill, or "slow burning" construction, as it is sometimes called, to distinguish it from fireproof construction, consists of brick, stone or concrete wall with wooden columns, timber floors, beams and thick blank floors, which although not fireproof, are all so heavy as to retard the progress of a fire and thus afford a measure of protection.

Reinforced concrete through the reduction in price of first class Portland cement and the greater perfection of the principles of design, has lately become a formidable competitor to both steel and

slow-burning construction because of its lower cost, shorter time of construction, and freedom from vibration, a competitor of slow-burning construction because of its greater fire protection, lower insurance rates, freedom from repairs and renewals, and even in many cases, its lower actual cost.

As a fundamental principle in mill and factory construction the cost must be such that the outlay for interest on construction, running expenses and maintenance, shall be at the lowest possible minimum consistent with conservative designs, and the requirements of operation. A wooden building is cheap in first cost and therefore in interest charges, but is expensive in insurance and repairs, while the risk of the loss in production after a fire for which no insurance provides may far counterbalance any theoretical saving. As a general proposition reinforced concrete is frequently the lowest priced fireproof material suitable for factory construction. The cost is nearly always lower than that for brick and tile, and with lumber at a high price, it is frequently even lower than brick and timber with the added advantage of durability and fire protection.

In comparing the cost of different building materials, one must bear in mind that the concrete portion of the building is only a part of the total cost. Since the cost of the finish and trim may equal or exceed that of the bare structure, even if the concrete itself cost, say, 10 per cent. more than brick and timber, the cost of the building complete may not be 5 per cent. greater than with timber interior. The lower insurance rates will partly offset this even if there is no other economical advantage for the fireproof structure.

The exact cost of a building in any case is governed by local conditions. In reinforced concrete, the design, the loading for which it must be adapted, the price of cement, the cost of obtaining suitable sand and broken stone or gravel, the price of lumber for forms, the wages of the laborers and carpenters are all factors entering into the estimate. Reinforced concrete is largely laid by common labor, so that high rates for skilled laborers affect it less than many other building materials.

While descriptions of modern factory buildings will be found in the following chapters, more especially under "Spelter Works," it seems that a description of the construction of an individual factory building is not out of place at this part of the book. We

select for this purpose the concrete factory building of the Pacific Coast Borax Refinery.

Pacific Coast Borax Refinery.

The distinction of being the designer and builder of the first two reinforced concrete factory buildings in the world undoubtedly belongs to Mr. Ernest L. Ransome, of the Ransome & Smith Co. Of these, the Pacific Coast Borax Refinery at Bayonne, N. J., a few miles from Jersey City, deserves a special attention not only as one of the earliest samples of this type of construction, but for its notable record in passing through a terrible fire, without structural injury. Moreover, the fact that it was not erected until 1897–8 serves to emphasize the marvelous growth in reinforced concrete construction.

The time is so recent and reinforced concrete buildings are now so common that it is difficult to appreciate the boldness of the conception to construct a 4-story building, to sustain actual working loads of 400 pounds per square foot besides heavy machinery even on the top floor, out of a material until recently used almost exclusively for foundations, and considered capable of resisting only compressive loads. Of course, the principle of steel reinforcement in concrete had been understood for a number of years previous to 1897. In fact a house of reinforced concrete was built in Port Chester, N. Y., as early as 1871, and a few other similar structures appeared between this date and 1897. But with the exception of the factory at Alameda, Cal., also designed and built by Mr. Ransome, the Pacific Coast Borax Refinery appears to be, as above intimated, the first attempt at concrete factory construction. While it is not claimed that the design of this factory is in all respects typical of the up-to-date concrete factory building as now erected by the Ransome & Smith Company and other contractors, many of its features and the methods employed in its construction are well worth consideration.

As built to-day, double walls are not regarded as essential for factories, but instead the wall surface is usually taken entirely by windows separated by concrete columns which support the floors above. In the floor system, slabs of longer span with correspondingly heavier beams are now more common, while expansion joints in floors are not usually specified unless the building covers an extremely large area.

Design.

The main building is 200 feet long by 75 feet wide, and four stories high, rising 70 feet above the ground. Connected with this and forming a part of it is a section which was built first only one story high, and then after the fire, carried up to the full four

Fig. 1. Pacific Coast Borax Refinery.

stories, as shown in Fig. 1. The area of ground covered by the combined buildings is 50,000 square feet.

The plan of the first story is shown in Fig. 2, the junction between the four-story and the one-story portion being indicated by the dot-and-dash line *AA*. In order to show the plan on a large scale, the first floor of the four-story building is drawn in full and a part of the one-story portion is omitted as indicated by the irregular lines *BB*.

The bays in general are 24 ft. 8⅞ ins. × 12 ft. 4⅝ ins.; the columns in the first story are 21 inches square, in the second story 19 inches, in the third story 17 inches, and in the fourth story 12 inches. They are computed by a maximum compression of 500 pounds per square inch.

The sectional elevation in Fig. 3 shows the columns and also the column footings which are reinforced in the bottom with horizontal rods. The footings were designed so that the compression upon the soil, which is of a marshy character, should not exceed 2,500 pounds per square foot.

Fig. 3 also illustrates the construction of the floor system, and,

taken in connection with a plan of a portion of the second floor in Fig. 2, gives a good idea of the type of design. Girders connect the columns which are 12 ft. 4⅝ ins. on centers. Between the girders and at right angles to them run the concrete floor beams about 3 feet apart and so thin and deep that they resemble timber joists in

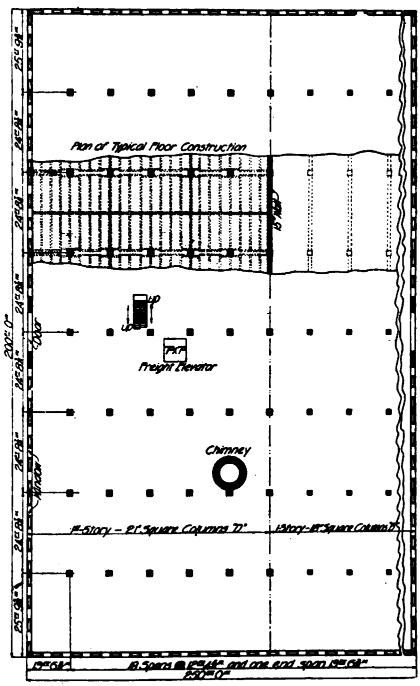


FIG. 2. PLAN OF FIRST STORY OF PACIFIC COAST BORAX REFINERY.

appearance. As these beams are nearly 25 feet long in the clear, a stiffening web crosses them in the middle designed to serve the same purpose as bridging in wooden floor joist construction, that is, to assist in preventing tendency to buckle under heavy loads. The girders are of rather peculiar construction, being made thicker in the panels next to the columns so as to save expense in forms.

Originally, the columns in the fourth story of the main building and also the roof were of wood, while the one-story part was of similar construction. After the fire, the wood was all replaced by concrete, as shown in the plans. The roofs were built as reinforced slabs of 12 ft. 4⅝ in. span from center to center of the beams, the latter being 24 ft. 8⅞ ins. long between column centers. Still later the roof of the low part formed the floor for the second story when

this portion of the building was raised to full height, as shown in the finished photograph, Fig. 1.

The reinforcement of the beams and girders and stiffness of the principal floors is shown at the lower part of the diagram (Fig.

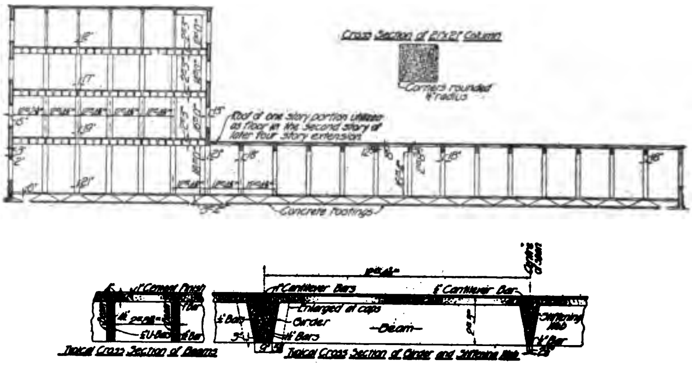


FIG. 3. CROSS SECTION OF BORAX REFINERY.

3). The slabs were built of such short span that they received no reinforcement, the depth being 4 ins. in addition to the 1-inch cement finish.

The floor with the beams and girders were laid as separate panels about 24 ft. square, a vertical contraction joint being carried down through the beams on a line with alternate columns; that is every eighth beam was built double. As stated above, it is not now customary to insert contraction joints, except on ordinary large sur-

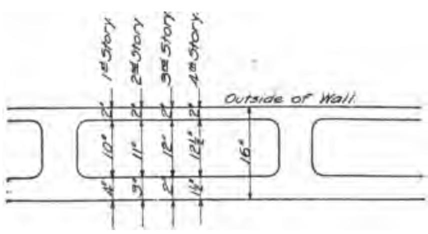


FIG. 4. TYPICAL HORIZONTAL SECTION WALL JOINTS.

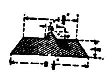


FIG. 5. MOULDING OF OF WALL.

faces, the contraction being provided for instead by the steel reinforcement in the beams and slabs.

Details of the hollow wall construction are presented in Fig. 4. The total thickness of all the walls is 16 ins. for the entire height of the building, the outer surface being only 2 ins. thick, and the

inner surface varying from 4 ins. in the first story to 1½ ins. in the fourth story. The length of the hollow spaces in the wall is variable, depending upon the number and location of the windows. The webs connecting the two walls are 3¹⁄₁₆ ins. thick on the north and south sides of the building and 4½ ins. thick on the east and

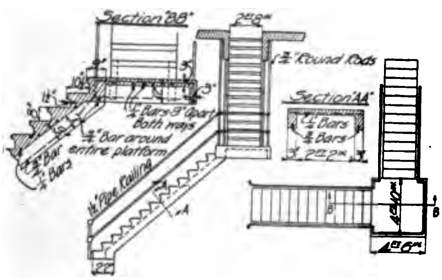


FIG. 6. SKETCHES OF STAIR CONSTRUCTION.

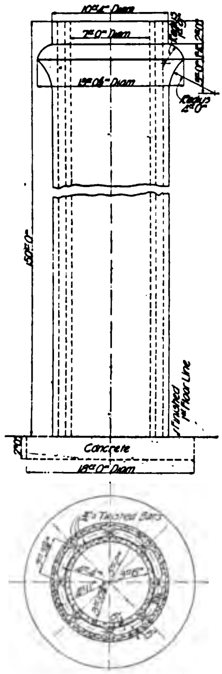


FIG. 7. PLAN AND ELEVATION OF CHIMNEY.

west. This hollow construction has proved satisfactory, and given a good roomy building with no consideration on the inner walls, but as previously stated, it is not now considered necessary in factory construction to incur the expense of coring out the walls and it is more usual to build them solid.

The exterior walls were finished by picking the surface with a sharp tool which removed the outside skin of cement so as to show the stone and mortar between and resemble pean hammered masonary. A part of this work was done by hand and part with pneumatic hammers. Although a pneumatic hammer averaged 400 square feet in ten hours, while by hand 100 to 150 square feet was a fair days' work for a man, the actual cost with the power tool was but slightly

less than by hand because of the higher grade of men required, the extra men for shifting air pipes, etc., and the wear and tear on the tools.

The surface was also divided into blocks by wood mouldings nailed to the inside of the form. A section of the moulding is shown in Fig. 5. The stairs are also of reinforced concrete, typical details being given in Fig. 6.

In Fig. 7 is shown the 150-foot concrete chimney which is located on the middle of the building (see Fig. 2). It was built with two independent shells of concrete.

Proportions of the Concrete.

The proportions of cement to aggregate in the concrete varied in different parts of the work. For the aggregate, broken basaltic rock brought down from the Palisades of the Hudson was chiefly used. The size was limited to particles passing a 2-in. ring, while for much of the work that which passed a 1-in. ring was employed. The dust was left in the rock and provided so much fine material that only a small quantity of sand, averaging not more than 10 per cent. was needed.

The proportions of the footings were 1 part Atlas Portland cement to 10 parts of this aggregate. The columns were of 1:5 mixture, and the walls, floors and stairs of 1:6½.

For imbedding the rods in the bottom of the floor beams a 1:6 mix was employed, using very fine stones for the concrete.

Concrete of 1:6½ proportions made into 3-in. cubes gave a compressive strength of 900 pounds per square inch at the age of 7 days.

Construction.

Construction was begun in the fall of 1897 and completed in October, 1898. The usual time per story was 40 to 50 days, whereas now such a building would be put up by the same builders at the rate of a story in one or two weeks.

The materials for the concrete included 10,000 barrels of cement and nearly as many cubic yards broken stone, the stone being brought in scows down the Hudson River and piled near the shed in which 1,000 bags of cement were stored.

The construction plant was of quite elaborate design. The cement having been wheeled from the shed, and the stone measured in bar-

rows, both materials were dumped into a hopper which discharged into a car. This car was hauled by cable through a subway and then up an incline to about 30 ft. above the hopper and about 400 ft. distant, where it was automatically tipped into a chute leading to the mixer. The mixer, of substantially the same type as the Ransome machines now in general use, discharged into a trough containing a screw conveyor which delivered the wet concrete to a vertical bucket elevator and this hoisted the material to the story where it was required, and dumped it upon a platform which held about one cubic yard.

A steam engine operated the car, mixer and elevator, and also ran a twisting machine, bolt cutter and two or three other tools. The column forms were built in the usual way with vertical boards paneled together and held with clamps surrounding them. The wall forms were 7/8 in. dressed boards, designed in general like Fig. 8.

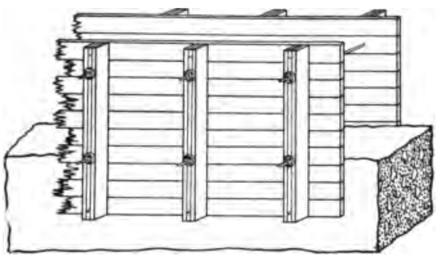


FIG. 8. TYPE OF WALL MOULDS.

These forms, patented by Mr. Ransome in 1885, are still extensively used in wall construction. The special feature is the vertical standard made of two 1 by 6 in. boards on edge with a slot between, through which pass the bolts. By loosening the nut, the plank behind the standards may be loosened and the standards raised. The walls were built in sections 4 feet high with central cores to form the hollow walls.

White pine was used for forms, and the salvage on the lumber probably did not amount to more than 10 per cent., although by present methods the builders usually figure about 30 per cent.

The total cost of the building was in the neighborhood of $100,000.

CHAPTER II.

THE LAYOUT, DESIGN AND CONSTRUCTION OF SPELTER PLANTS.

The manufacture of spelter at large generally comprises the pulverising and roasting of sulphide ore, the utilization of the sulphurous acid gas, the reduction and distillation of the zinc and the manufacture of retorts and firebricks in a suitable pottery. A gas producer house is also provided in most cases.

As regards the quantity used, coal is the most important material in the zinc industry. This is the reason why zinc plants are always and have to be located in the vicinity of coal deposits, while the ore and clay may be obtained from distant regions. This fact determines the general location of a zinc plant, while the relative location of the various buildings is determined by the size and shape of the space at disposal and by the sequence of the operations to be performed in the entire manufacturing process.

Where natural oxidic zinc ores are used, the roasting process, of course, is done away with, whereby the compactness of the plant is considerably increased. Such a plant simply consists of a producer house, pottery and distillery.

We will now describe the most modern British spelter plant, namely the works of the Central Zinc Company, near Seaton Carew. In these works, which employ from 300 to 400 men, all the appliances are of the latest and most improved type, and the methods employed embody the most recent knowledge on the subject. The ore, in the form of concentrates, is roasted in special furnaces, where it is oxidized; the sulphurous acid fumes are converted into sulphuric acid in a separate plant; the ore is cooled, mixed with reduction coal and charged into furnaces of the recuperative type, where the zinc is distilled off as a vapor, and, after being collected in a metallic form in condensing pipes, is cast into moulds as spelter.

The Seaton Carew Works are laid out for a capacity of about 35,000 tons of zinc blende per annum, which means from 10,000 to 12,000 tons of spelter per year. The amount of sulphuric acid manufactured is also considerable, being approximately equal to the

weight of concentrate roasted. A plan of the works, showing the disposition of the buildings, is given in Fig. 9.

Interesting as the process of zinc-smelting in these works is, it is not with this, however, that we are at present so much concerned as with the construction of the buildings, which are in many ways novel, being built entirely of steel and concrete. Several of the buildings were designed and carried out by Messrs. Nicholds and Reynolds, King's-court, Broadway, Westminster, S. W., whose system of steel and concrete slabs enabled them to be erected expeditiously.

One of the most important buildings is the pottery. Its position may be seen in the general plan, Fig. 9, and it is shown in detail in

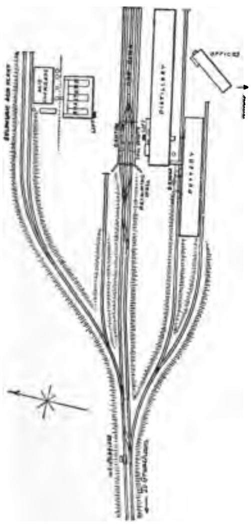
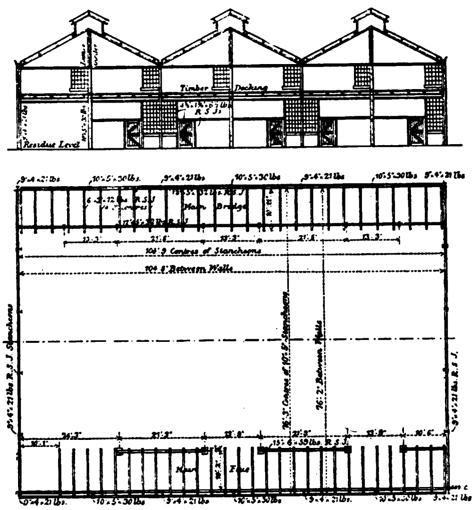


FIG. 9. PLAN OF SPELTER PLANT.

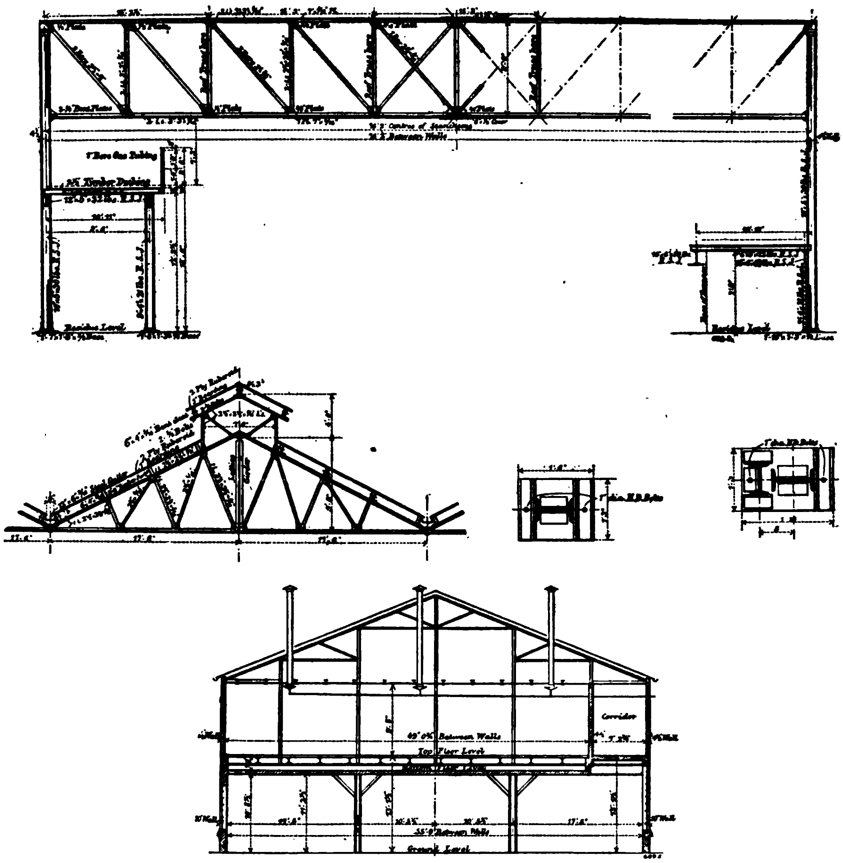


FIGS. 10–11. ELEVATION OF BUILDING.

Figs. 16 to 22. Fig. 12 is a transverse section through the building, showing an end wall; while Fig. 16 is a half-transverse section showing one of the roof principals, floor girders, etc. Fig. 18 shows the method of constructing the ventilator, while Fig. 19 illustrates one of the windows. The longitudinal channels between the stanchions which carry the roof principals may be seen in Fig. 20. The method of constructing the gutters is illustrated in Figs. 21 and 22.

The pottery building, as the name implies, is where the retorts, pipes, etc., which are used in the zinc-smelting process, are made. It

is 315 ft. long and 55 ft. 9 ins. wide inside, and at one end has two rooms, which run the full width of the building, and are 50 ft. long. They contain the motors, elevators, crushing machinery, pug-mills, and presses for manufacturing the fireclay pots used in the process of zinc manufacture. The bottom floor of the remainder of the

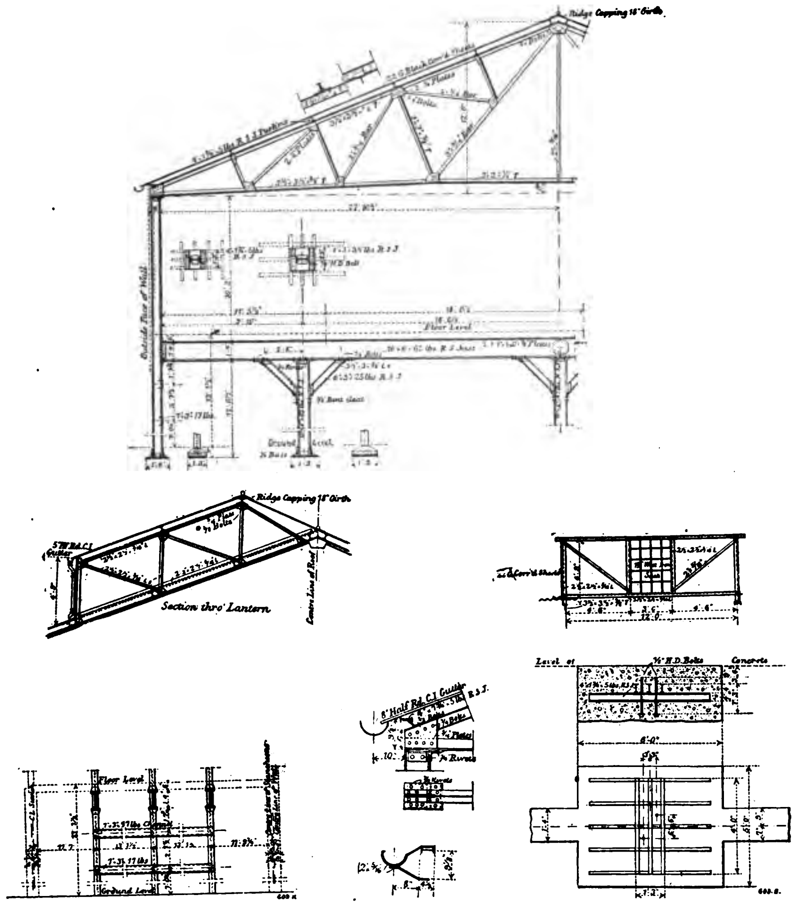


FIGS. 12–16. DETAILS OF CONSTRUCTION.

building is left open, and the waste gases from the distillery furnaces are carried through flues underneath, so as to dry the clay which is stacked above. The upper floor of the building is divided into 15 chambers, which are heated by steam for drying the pots and pipes. A corridor runs the entire length of the building in front of the chambers, and has a cross-passage which leads over a bridge to the distillery. This bridge may be seen in the general plan, Fig. 9.

The upper floors are all constructed of reinforced concrete, with a 2-ft. gauge tramway, and turntables embedded, on which run the bogies carrying the pots.

The building itself is a steel panel structure, the walls and partitions of which are built with hollow machine-made concrete blocks, moulded on the site from selected slag from furnaces using Cleve-



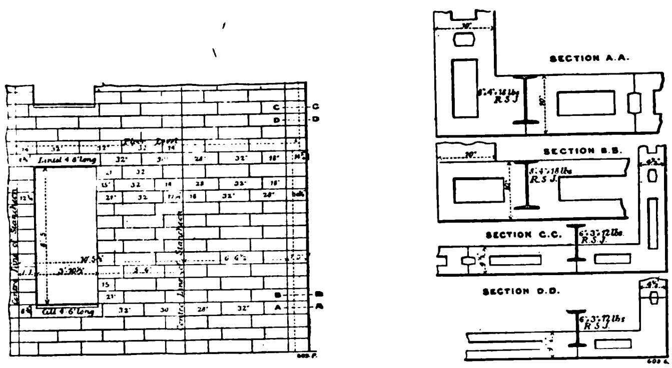
FIGS. 17–24. DETAILS OF CONSTRUCTION.

land ore. The slag is annealed before crushing, and then broken to pass through a ⅜ in. ring. The roof of the building is of corrugated sheeting, but below this and over each chamber a ceiling is formed of steel framing and asbestos sheets; the chambers are also fitted with fire-proof air-tight doors constructed with asbestos sheeting on a steel framework.

The method of forming the concrete walls is clearly shown in Figs. 26 to 30; the first of these represents a portion of wall with various blocks assembled in position, while the remaining four figures are larger scale horizontal sections taken at different points, as shown by the section lines in Fig. 26. The blocks for the outer walls are 10 ins. thick, 32 ins. long, and 9 ins. deep, and have a cavity in the center $3\frac{1}{2}$ ins. wide. Those of the upper walls and

FIG. 25. PLANT DURING ERECTION.

partitions are $4\frac{1}{2}$ ins. thick by 32 ins. long by 9 ins. deep, with a cavity $1\frac{1}{2}$ ins. wide in the center. These illustrations are so clear that any further remarks with regard to this method of construction are hardly necessary. It may, however, be said that these



FIGS. 26–30. DETAILS OF PLANT.

blocks, dovetailed together as they are by cement dowels in the spaces shown and set in cement, appear to make an excellent wall, cheap, waterproof, rapidly constructed and of great strength. The

stanchions which support the concrete blocks are carried on a steel grillage foundation, which is bedded in concrete, as shown in Figs. 23 and 24. This form of foundation gives great stability to the stanchion.

The floors of the drying chambers are double; that is to say, above

FIGS. 31–33. OUTSIDE VIEW OF PLANT.

the reinforced concrete a second floor of timber grids is provided, and between these two floors are the heating pipes for drying the pots and pipes which stand upon the timber grids. Each chamber is about 47 ft. long and 17 ft. wide, and is perfectly air-tight. It has to withstand a temperature sufficient to dry the pots, and is provided in the bottom floor with eight large hit-and-miss ventilators and in the ceiling with three ventilating shafts, which pass through

the roof to the outside. They are to facilitate the control of the heat and the carrying-off of the condensation. They are clearly shown in Fig. 16.

Each chamber, when full, contains 300 to 400 retorts, which weigh about 300 lbs. each. From this it will be seen that the loads on this building are somewhat excessive, and as the whole of the site is composed of sand, the special form of spread foundation for the stanchions, to which we have before alluded, was adopted, so that not more that 1 ton per square foot is transmitted to the ground.

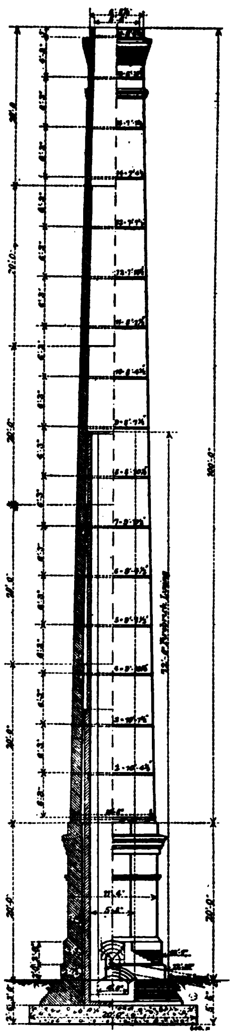


FIG. 34. CHIMNEY.

The ground floor has been laid partly in open concrete work, and partly in concrete paving slabs 2½ ins. thick, the whole of the concrete being made of slag, as previously described for the wall blocks, with the exception that for the mass work in the reinforced floors it was crushed to pass through a ¾ in. ring. The top surface of the floors and paving was worked up with specially prepared slag to withstand heavy traffic, such as barrows, trolleys, etc., in addition to the traffic on the tram lines.

The roaster building, which may be seen on the plan, Fig. 9, close to the acid chambers, is also a steel panel structure, about 105 ft. long by 76 ft. wide, and contains the furnaces in which the ore is roasted prior to distillation, the gases generated during the process passing off to the sulphuric acid chambers. The walls of this building are 4½ ins. hollow concrete blocks, made and put together in a similar way to those used in the pottery building. The roaster building is shown in sectional elevation and in plan in Figs. 10 and 11. An enlarged longitudinal section may be seen in Fig. 12, and an elevation of one of the roof principals in Fig. 13. Sections of some of the stanchions are given in Figs. 14 and 15. A special feature of the construction is the roof, which, in order to avoid the use of

internal stanchions, has been made on the cantilever principle, as will be seen on reference to Figs. 12 and 13. Under the apex of each span there runs a lattice girder the whole length of the building, and each of these girders carries the whole weight of one span of the roof, together with its covering, which consists of a layer of boarding, over which ruberoid is placed. Large open ventilators are provided over each furnace, the construction being shown in Fig. 13. A bridge is provided at one side of the building for the

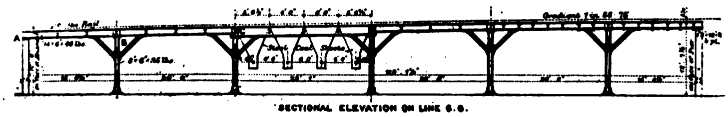


FIG. 35. SECTIONAL ELEVATION.

tramway which conveys the ore to the furnaces. The ground floor of this building is laid in a similar manner to that of the pottery building—that is, part open concrete and part 3-in. concrete paving-slabs.

Leaving the roaster buildings we naturally come to the distillery building, where the roasted ore undergoes the process of being heated in special furnaces, so that the zinc is distilled off and condensed in

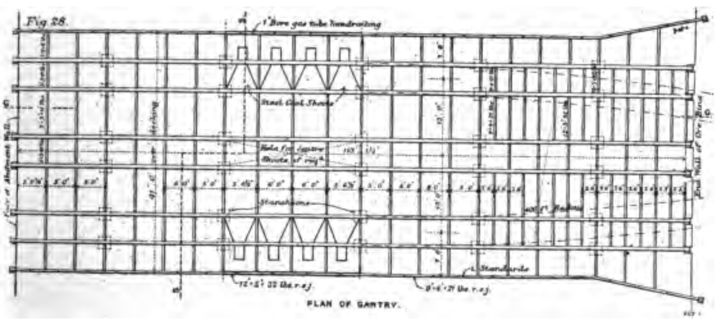


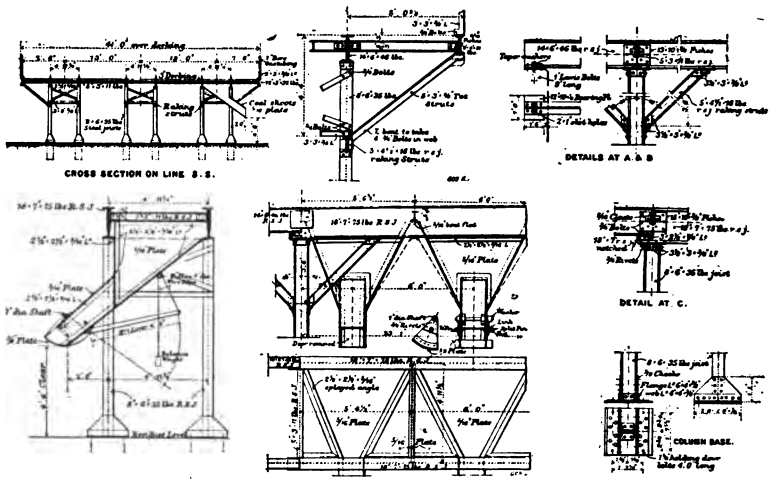
FIG. 36. PLAN OF GANTRY.

special pipes. We need only say that it is a steel building, 414 ft. long by 56 ft. wide, covered with galvanized corrugated iron. There is an upper floor of reinforced concrete, which has been specially designed to take heavy loads without vibration from the traffic along the tramlines. The lower floor is similar to that in the roaster building. Outside this building, and adjacent to it, are provided platforms and gangways. These are steel framed structures, with

reinforced concrete floors between the buildings and the lifts over the gas producers which supply gas to the furnaces.

In connection with the roaster building and for the distillery there are two chimneys, the one for the former building being 105 ft. high and 4 ft. in diameter inside; while the latter has a height of 120 ft. above the ground, and an internal diameter at the top of 5 ft. 6 ins. In construction they are similar, and are built on the Custodis principle. The chimney for the distillery is illustrated in part sectional elevation in Fig. 34, from which a very clear idea of its form and construction may be gathered.

An important part of this installation is the gantry by which the train-loads of ore are conveyed from the siding to the ore-bins. Its position may be seen in Fig. 9; but its general appearance



FIGS. 37–47. DETAILS OF PLAN.

and the details of its construction are shown in Figs. 35 to 44, the first three of these being an elevation, a plan, and a section respectively, while the remaining figures illustrate details of the structure. The gantry is 115 ft. long by 40 ft. wide, and has on it three lines of railway. It is built of steel girders and stanchions, so as to take the heaviest engines. It will be seen from our illustrations that the gantry is provided with eight coal-shoots—four on each side—for handling the coal. These shoots are shown in detail in Figs. 45, 46 and 47. The door at the bottom of each shoot is curved, and is so hinged that it slides over the mouth of the shoot, and closes up the

opening in such a way that it is impossible for the shoot to become blocked up at this point. The door is actuated by a lever and weight as shown. The bins in which the ore is stored are thirteen in number, and they have been constructed in reinforced concrete on the Coignet system, so as to allow standage for thirty-nine 20-ton trucks.

The whole of the plant is driven electrically.

CHAPTER III.

THE LAYOUT, DESIGN AND CONSTRUCTION OF PORTLAND CEMENT PLANTS.

The success of a Portland cement plant depends primarily on the suitability of the raw materials, that is whether their chemical composition will produce the best cement at the lowest cost. The raw materials used for Portland cement in this country have varied during the last few years; previously the industry confined itself largely to an argillaceous limestone or to a mixture of marl and clay. Mills were afterwards erected which used limestone and clay or two grades of limestone. Later on experiments made with furnace slag to which was added a suitable limestone, and both burned in a rotary kiln, gave a satisfactory grade of Portland cement; likewise the results obtained in experiments with the waste at the caustic soda plant of the Michigan Alkali Company. The first problem in the erection of a cement plant is naturally therefore the investigation of the materials from both a chemical and engineering standpoint.

The samples should be carefully selected from the deposits and a complete chemical and physical investigation made covering the adaptability of the ingredients, and the lines followed should be similar on a small scale to the process to be employed in the contemplated works. A small amount of cement should be manufactured after the chemical analyses of the raw materials show the proper mixture, and physical tests made of the finished cement. Accompanying these experiments and as a part of the investigation, a careful examination of the deposits should be made in order to ascertain their general conditions, such as the shipping facilities; extent of the deposits; relative location of one deposit to the other; the best process to be employed for particular conditions and requirements; the most favorable location for the plant, and also the best size. These governing factors are first carefully studied and the data and results embodied in a general report, together with recommendations upon the character of which depends the erection of the plant. Such an investigation requires the services of engineers and chemists thoroughly skilled, not only in the design and erection of Portland cement plants, but also their operation. More

valuable still are the services of those who have had experience in the erection of plants which have utilized various raw materials in order to accomplish the same results.

The early history of the Portland cement industry indicates that little or no attention was paid to engineering features in the construction of plants. Economy in construction and operation naturally followed what may be termed the experimental period when the commercial success of the rotary kiln was altogether problematic. The first plants were erected by experimenters and represented mere growths, as additions and extensions were made from time to time in order to improve apparent defects. Gradually, however, as the rotary process was perfected, more careful study was given the question of economy in operation, and this naturally required the services of trained and skillful engineers, who had acquired intimate knowledge by their associations during the experimental period. The plants which represent tentative construction are being fast superseded by those erected from comprehensive plans and specifications in which the most minute details are carefully studied and advantage taken of local conditions. The principal requisites of a modern cement plant to-day are large capacity and low cost of manufacture, and these are only attained by careful design and construction. A cement plant can be divided into four general divisions: First, the mill proper; second, the power plant; third, the auxiliary departments; fourth, the raw material deposits and their equipment.

1. The selection and arrangement of the machinery in the mill proper depends altogether on the character of the raw materials and the general conditions to be met, surrounding the site for the plant. Mechanical devices should be used wherever possible in order to eliminate manual labor and make the process as nearly automatic as possible. Provision should be made for carrying a considerable quantity of the materials in its different stages of manufacture, so that in case of a breakdown in any department, stoppage of the entire plant will not necessarily follow. All machinery and apparatus should be of simple, heavy design and the construction arranged for ready access at all times.

2. The power plant should be so designed that a maximum saving is obtained in generating the required amount of horse power. Advantage should be taken of every economic condition in installing the engines, which with the steam accessories should be of the most

efficient type. The practice of dividing the required engine and boiler power into convenient units has been found most economical, with an excess ever ready in case of emergency.

3. The laboratories, machine shops, cooper shops, pumping station, etc., usually classed as the auxiliary departments of a plant should be so thoroughly equipped as to render outside resources unnecessary and assist in maintaining the cost of production at a minimum.

4. The equipment for operating the raw material deposits should

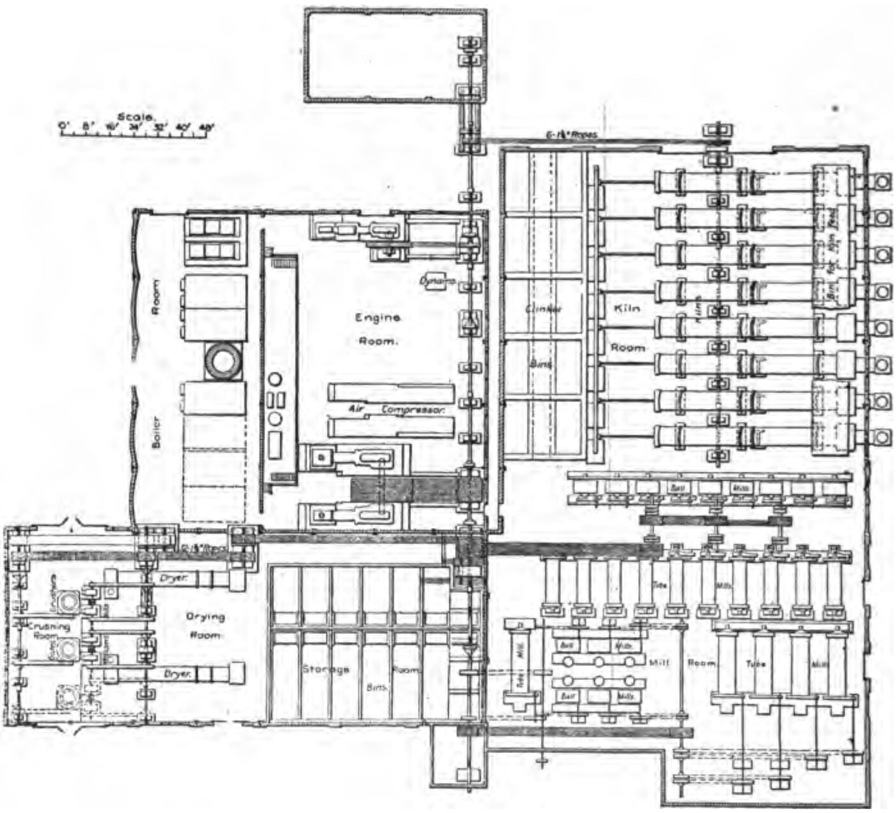


FIG. 48. GENERAL PLAN OF MILL BUILDINGS OF SIEGFRIED CEMENT PLANT.

be so adapted to the particular materials as to insure a full and constant supply at all seasons of the year, and the relative location of deposits to plant should be such that the materials are readily accessible and quickly transported by short hauls to the grinding and mixing departments. Machinery for transporting the materials to

the mill should operate at the lowest cost and meet the peculiar requirements of the materials themselves.

These four subdivisions are each dependent on the other in order to make up a composite whole, which represents the plant. But each division performing certain independent functions is again divided into the main departments of manufacture.

The general design and arrangement of these departments depend largely on local conditions and the amount of money to be spent in constructing the plant. Long experience, however, has demonstrated that the very heaviest and best machinery is none too good in a Portland cement plant, and if a saving is necessary, it should be effected on the buildings and not at the expense of the mechanical equipment, as the wear and tear in this particular line of manufacture is probably greater than in any other industrial enterprise. The constant and steady operation of the different machines, which, generally speaking, are operated nearer 24 hours than 10 or 12 hours renders impossible extensive repairs without causing a shut-down to the whole plant; and thus it is that Portland cement works require a complete overhauling once each year.

While the foregoing shows the importance of entrusting the design to skillful hands, it is just as necessary to the ultimate success of the plant that the construction should be supervised by the same parties. The success of many an enterprise is endangered by incorrect interpretation of specifications and design, and this is especially true in the erection of a cement plant. The necessary care and vigilance of parties familiar with both the design and operation are continually required during the course of erection and until the plant is ready to operate, after which follows the most critical period in the life time of a plant. From the time the various departments are set in operation, until the entire plant is running smoothly and successfully the direction should be entrusted absolutely and entirely to experienced hands. Unfortunately the converse of this has been true in a large number of plants erected in this country, during the past few years, by capitalists without the least knowledge of their operation. In these instances they became incapacitated in a few months and required rebuilding, thus doubling the first cost of construction and entailing a heavy loss to the investors.

A plant to be successful should be designed and constructed by experienced engineers and afterwards operated under their management until in successful running order, then turned over to

skillful operators who have become thoroughly familiar with the process and machinery employed.

Some Examples of Modern Installations.

In the brief descriptions of the rotary plants which follow, we have selected those operating successfully under the most diversified conditions of manufacture. The cuts for the various plants were made from working plans, and were selected in order to include the most interesting features of American engineering practice.

Lawrence Cement Company of Pennsylvania (Siegfried, Pennsylvania).

The buildings constructed of steel and brick are fire-proof throughout. The plant, a plan of which is shown in the cut, includes mill, kiln, engine, boiler, fuel buildings and stock house, the latter although not shown on the drawing is located north of the mill building and runs parallel with the kiln building. Advantage was taken of the natural slope of the ground and a gravity system utilized for handling both raw materials and coal.

The buildings were designed to allow for extension in any department, and provision has been made in the present engine house to install 2,000 additional horse power, and in the boiler room space has been provided for the installation of 1,000 H.P. additional. All buildings were designed and erected with clear spans. The roofs of the kiln, boiler, engine and fuel buildings being covered with 24-in. porous terra-cotta tile supported on T bars, which in turn rest on the roof purlins. A covering of slate was nailed over this tile. In the other buildings the slate was nailed on 2-in. sheathing. At the gable ends of building arched doorways were provided, but temporarily bricked up. These can at any time be opened when the buildings are extended. Where drops in the ridge levels occur, the gables were covered with corrugated iron. The east wall of the boiler room is constructed of concrete, and arches of 43 ft. radius are sprung between the columns. These arches forming one side of the coal bunkers resist the pressure of the coal, while the resultant thrust is transferred to the steel columns of the building. This method of construction was used in place of heavy retaining walls. Coal from the bunkers flows by gravity into the boiler house through doors located in the arches at the level of the floor.

Cement is manufactured from an argillaceous limestone, commonly known as cement rock with about 20 per cent. of limestone added to supply the deficiency in lime content. The cement rock quarries have been opened along the bluffs of the Hokendauqua Creek, and the lower levels of the mine are reached through a double-tracked tunnel constructed as an inclined plane. The mine equipment is most complete, being operated by compressed air fur-

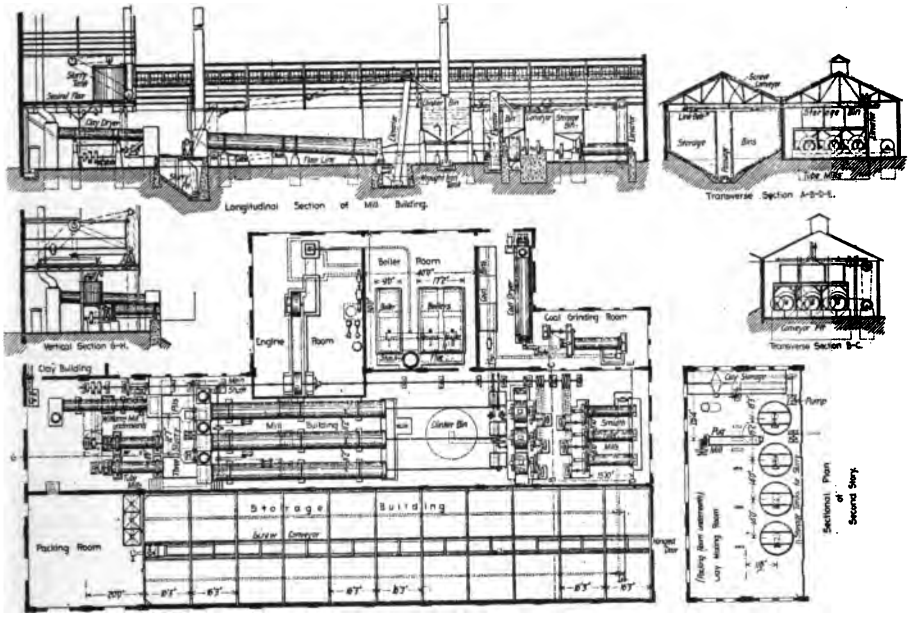


FIG. 49. GENERAL PLAN AND SECTION, MICHIGAN ALKALI CO.'S CEMENT PLANT.

nished from the engine house. Specially designed cars are used for transporting the material from the quarries to the mill, and the material is discharged directly from the cars into the crushers located underneath the tracks entering the building. Limestone is brought in on one track and cement rock on the other, each being reduced separately. From crushers the material falls to a battery of four disintegrating mills located in front of the crushers. The material is then passed to rotary dryers, from which it is elevated and conveyed to self-emptying storage bins constructed with wood sides and concrete bottoms. Located directly under the central partition line of these bins is a large tunnel. Running the length of this tunnel are two conveyors which carry the material as it is discharged from

the bins to elevators located at the far end of the tunnel which discharge the two materials into the hoppers feeding the weighing and mixing machinery. From here, the correctly proportioned raw material is conveyed to ball mills where it is ground to pass through a 30-mesh sieve. From ball mills the material passes to the tube mills where it is finished and conveyed to the bins supplying the rotary kilns. These bins, each having a capacity for 48 hours run, are located over the rotary kilns into which the raw material is conveyed through water-jacketed chutes.

Pulverized coal forced into the discharge end of the kilns by an air blast is used to burn the clinker. Each pair of kilns is provided with an elevator which lifts the clinker as it is discharged from the kilns and spouts it into cooling bins. These bins, with a capacity of 20,000 barrels, are constructed of brick masonry with an arched passage-way running under their entire length. The clinker is cooled by a blast of cold air forced in at the bottom of the bins which are self-emptying; it is then discharged through chutes into tunnel cars and hauled to an elevator; similar cars operated on overhead track carry it from the elevator to the ball mill bins. The clinker is subjected to preparatory grinding in ball mills and then finished in tube mills, after which the cement is elevated and conveyed to the stock house which is arranged with two aisles and four rows of self-emptying bins. The cement flows from the bins into conveyors which carry it to the packing department where automatic sacking and barreling machinery prepares it for shipment.

In addition to the manufacture of Portland cement, there are six steel vertical kilns for producing natural cement. These kilns are so arranged that the cars from the quarry can be run directly into the steel housing constructed on top of the kilns and the raw rock discharged. The coal is elevated from the storage bunkers and distributed ready for use along the tops of the kilns. The clinker is drawn out through the arched openings built in the masonry foundations of the kiln, then loaded on cars and transported to the mill room located nearby. Coal for burning the cement is stored in bunkers built underneath the railroad trestle running beyond the boiler room. From the bunkers near the coal-grinding building the coal falls by gravity to the elevator and conveyor feeding the rotary dryer, from which it passes to the grinding machinery. The powdered coal is afterwards elevated and conveyed to the supply bins located in front of the kilns.

The power plant includes one cross compound condensing engine of 1,200 H.P., one tandem condensing engine of 175 H.P., one 400 H.P. air compressor and two generators aggregating 250 K.W. Steam is furnished by six 250 H.P. water-tube boilers. Both engines run condensing, and as the water supply was poor, a Wheeler surface condenser was installed so that the condensed steam could be used for boiler feed purposes.

The power transmission machinery was heavy and substantially designed to meet the excessive strain it is subjected to. The various machines themselves are driven by belts from line shafts, while rope drives are used to transfer power from main line shaft to auxiliary shafts. The large engine also drives to the main line shaft by the separate rope system. The heaters, condensers, pumps and hot well are all installed in a large pit located in the engine room, which feature has the advantage of leaving the floor clear of these accessories.

The entire plant and surrounding grounds are lighted by electricity. Besides the main buildings, the plant also includes well-equipped machine, blacksmith and cooper shops, with the necessary storage and supply houses, making the plant entirely independent in the matter of replacement or repairs.

The design of the entire plant was carefully studied in order to reduce manual labor to a minimum, and mechanical means introduced wherever possible to accomplish the purpose.

The Michigan Alkali Company's Plant, Wyandotte, Mich., For Manufacturing Portland Cement from Caustic Soda Waste.

The accumulation of waste product from the caustic soda plant, at the rate of over one hundred tons a day, necessitated providing means for its disposal. An investigation respecting its adaptability as a lime ingredient of Portland cement was decided upon, and the experiments and later the design and erection of the plant placed in the hands of the Spackman Engineering Co., of Philadelphia, Pa.

The raw materials were the waste from the caustic soda plant and the blue clay from the property of the company on the Detroit River. This waste, owing to the company's having employed the ammonia soda process, was comparatively free from sulphur compounds, although experiments indicated that the waste from the

English process could be as successfully used. After several trials, a hard burned, dark green crystalline clinker was produced from the mixture of 100 parts of clay to 260 parts of waste by weight, and tests showed the quality to be equal to the best of American or imported cement.

The plant was erected on the low lands bordering the Detroit River. High grade materials were used throughout and the process made practically automatic. The buildings, constructed of steel with brick sides, have clear spans; the trusses being carried on brick pilasters. As water and quicksand was discovered at two feet, the walls were built upon brick arches which transferred the entire weight to concrete piers extending to solid ground.

The mill building and stock house are parallel twin buildings, each with a 42-foot clear span; at the north end the roof is raised and 84-foot trusses span the width of both buildings, giving room for a second story. Adjoining the mill room but separated by brick partitions are the coal grinding, the engine and the boiler rooms. The clay building, with a 30-foot span, is of steel and corrugated iron and runs towards the river at right angles to the mill building.

The waste material is transported to the mill by a traveling crane, which, securing a charge in the soda plant, transports it into the second story of the cement plant. The clay, after excavation, is stored in the clay building, from which it is conveyed to an elevator, discharging into a rotary dryer, where it is subjected to the direct heat of a coal fire and afterwards passed through a disintegrator from which it is elevated to the second floor and discharged into steel bins, ready to be added to the lime waste.

The raw mix passes through a pug mill on the second floor, which discharges into a storage tank directly underneath. This tank is provided with agitators which prevent any separation by settling. From this tank the slurry flows to wet grinding tube mills for a final reduction. These discharge into concrete pits, so arranged that a high lime or clay surry can be discharged into any of them to correct the chemical composition. After being analyzed and corrected if necessary, the material is pumped to steel storage tanks located in the second story. Agitators keep the slurry in motion in all pits until pumped into the rotary kilns. The material is fed to the kilns through water-jacketed chutes as slurry and burned to a clinker with pulverized coal; all three kilns discharge

into a concrete pit, from which it is elevated to the cooling towers.

Air is forced in at the bottom of these steel cooling towers, 12 ft. in diameter and 22 ft. high, arranged with a succession of metal floors, having radial openings, through which the clinker is swept by a scraper fitted to a central shaft. The clinker is moved 350 degrees on each floor, before falling to the next. Arriving at the bottom, it is elevated into steel bins over the ball mills, from where it is raised and conveyed to bins over tube mills which finish the cement.

From here the cement is elevated and carried by an overhead conveyor, through the mill room wall, into the stock house, and discharged into two lines of conveyors resting on the top of the storage bins, thus delivering it into any bin desired. These bins have hoppered bottoms and are arranged in two rows with a passageway between containing two lines of screw conveyors; these carry the cement drawn from the bins to an elevator at the packing room which discharges it into the bins supplying the packing machinery.

The power plant consists of one 600 H.P. tandem compound condensing engine, and three water-tube boilers. The river water passes from jet condensers to hot well from which feed water for the boilers is taken.

The engine is belted directly to the main line shaft which passes through the engine room walls in stuffing boxes, thus cutting out the dust from the mill; the engine room projecting beyond the walls of the mill so as to give clearance for main shaft. The shafting is so arranged that the power can be cut out from any department by the use of clutch couplings.

A notable feature of the plant is the relatively small area covered by the buildings when compared with the total capacity, making it one of the most complete plants in operation. Including the stock house with a capacity of 40,000 barrels, all the buildings cover an area of only 25,000 square feet, and the plant has a daily average of 450 barrels.

Mechanical Equipment

The endeavor of American designers of machinery for use in cement mills has been to intensify the production; increasing the output and decreasing the amount of material in process of manufacture, and to use mechanical means for the handling and moving of material wherever possible.

Labor-saving devices are universally used in getting out the raw materials from the deposits. Hoists, aërial cable ways and tramways facilitate the handling of the material, and power drills are installed where quarrying is to be done; the softer materials being excavated with steam shovel or dredge.

In the mill proper the size and capacity of all the machines have been greatly increased. For breaking down the rock, crushers of the jaw or gyratory type are used. If the materials are soft, they are broken down in disintegrators and pug mills. For preliminary grinding ball mills, comminuters, centrifugal hammer machines, fine crushers, rolls or dry pans, all find advocates.

For finishing the raw materials and cement there are a number of machines in the market, but the tube mill is most used. For burning cement in America, rotary kilns have superseded all others, and rotary dryers are given the preference in the majority of mills. There seems small probability of a radical change in the heavy machinery beyond improvement in details which may further reduce wear and tear and increase the capacity. The greatest changes in the future will probably be found in conveying and elevating devices. This part of the equipment caused trouble in the past, due largely to the adoption of apparatus which, while working satisfactorily on other materials, was unsuited for the requirements of cement manufacture. The past few years, however, have witnessed great improvement in conveying machinery, the builders becoming more familiar with the conditions surrounding their use. The conveying of the ground materials has given less trouble, screw and belt conveyors being installed for this purpose, but the conveying and cooling of the hot clinker and the raw materials from dryers requires apparatus of special design. For elevating, some form of heavy and slow-speed chain belt bucket elevators are used, replacing the lighter and cheaper apparatus formerly in use.

In the generation and transmission of power great improvement has been effected, the low pressure boiler being largely superseded by high-pressure water-tube boilers of both horizontal and vertical types, the latter being recently introduced; the makers claiming they are especially adapted to the use of water that carries lime and other scale-forming materials which is so frequently encountered in the neighborhood of deposits for cement manufacture, and that the tubes can accumulate no soot or flue ash outside, nor loose scale inside.

Compound condensing engines are now universally used, while electrical transmission of power is fast taking the place of shafting. Though these changes have increased the cost of installation and made the mechanical equipment more complex, the resultant saving in cost of manufacture has been great, and to-day cement can be profitably sold at prices once thought impossible.

CHAPTER IV.

THE LAYOUT, DESIGN AND CONSTRUCTION OF STEEL AND IRON PLANTS.

THE GARY PLANT.

The entire Gary plant is driven by individual induction motors, located wherever power is required. Current is carried at high voltage on an intricate distributing system from a central power house. Here in one building is the driving plant upon which complete dependence is placed for the operation of the various machinery and mills. The electric generators here installed are driven entirely by gas engines using blast furnace gas. The same motive power is used for the blowing engines for the blast furnaces. The use of blast furnace gas for power purposes is an established practice, including the methods installed at Gary for washing the gas, but such installations as comprise the two blowing engine plants and central power house in which are a total of 33 twin-tandem gas engines aggregating a combined rated capacity of 108,000 horsepower, are without parallel. In this country, at least, this is a distinct advance.

The rail mill, which is unique in being almost a continuous mill, is driven by motors ranging from 6,000 to 2,000 horsepower capacity, on a 6,600-volt circuit. A few years ago, 220 volts was a maximum pressure for mill service, with all of its dust. At Gary the situation from the standpoint of distribution of current practically compelled the use of high voltage in order to reduce the diameter of the conducting cables, both because of the resulting economy in copper and the improved power factor. While the motors doubtless have been well insulated, the service will be severe and will be watched with much interest.

The present Gary plant, completed or in the process of erection, comprises: A vessel slip and turning basin; ore yards with a capacity of 2,500,000 tons; five unloaders; five ore bridges; ore, coke and stone bins with a capacity for 42 hours of operation for each stack; eight 450-ton furnaces; three primary washers for each two stacks or 12 in all; one cinder tank for each two stacks or four in all; two boiler houses, one containing eight batteries of two Rust boilers

each, for furnaces nos. 9 and 12, the other containing a similar outfit of Stirling boilers for furnaces nos 5 to 8; two Zschocke and two Theisen washers to each stack or 16 of each, in all; two blowing engines for each stack and two extra steam blowing engines for furnaces nos. 9 to 12; two gas holders; one building in which are combined power stations nos. 2 and 3, containing two 2,000-kilowatt generators with two twin-tandem direct-connected gas engine driving units, for each furnace or 16 in all, and one auxiliary gas-engine generator set and two steam turbines for eight furnaces; a central pumping station; a pig casting plant of six machines; a ladle repair shop; a skull cracker and blast furnace brick storage; four open-hearth buildings nos. 1, 2, 3 and 4, each containing a battery of 14 60-ton stationary furnaces; a skull cracker between each two buildings; two ingot strippers, nos. 1 and 2; one refractory brick storage building for each open hearth; an aggregation of 70 10-foot hand-poked gas producers for each open-hearth, or five to a furnace; soaking pits for rail and billet mills, 12 for each mill; each pit accommodating 16 ingots; 24 mechanically poked gas producers for the soaking pits; rail mill and finishing mills with an estimated capacity of 100,000 tons a month; billet mill with an estimated capacity of 100,000 tons a month; a merchant scrap yard for the general handling and preparation of scrap for Gary and other Steel Corporation plants; machine shop; foundry; boiler shop; locomotive house; storehouse; brick shed; clock house and stable.

These various departments will be taken up in detail in the following pages. It may be said with regard to the open-hearth buildings that only nos. 3 and 4 are nearing completion.* The foundations for open hearth no. 1 are in and the fabricators are working on the steel for the building. Work on no. 2 was prevented at the time the other open-hearth foundations were being put in, because the former right of way of the Baltimore & Ohio Railroad passed directly over the site, and had not yet been abandoned. This building will be a part, however, of the plant as contemplated for immediate completion. The ingot strippers now to be used for open hearths nos. 3 and 4 are strippers nos. 1 and 2, the erection of nos. 3 and 4 being held up for the further filling in of the shore lines. The further construction includes eight additional blast furnaces with ore-handling equipment, gas washers, blowing engines, power

* 1909.

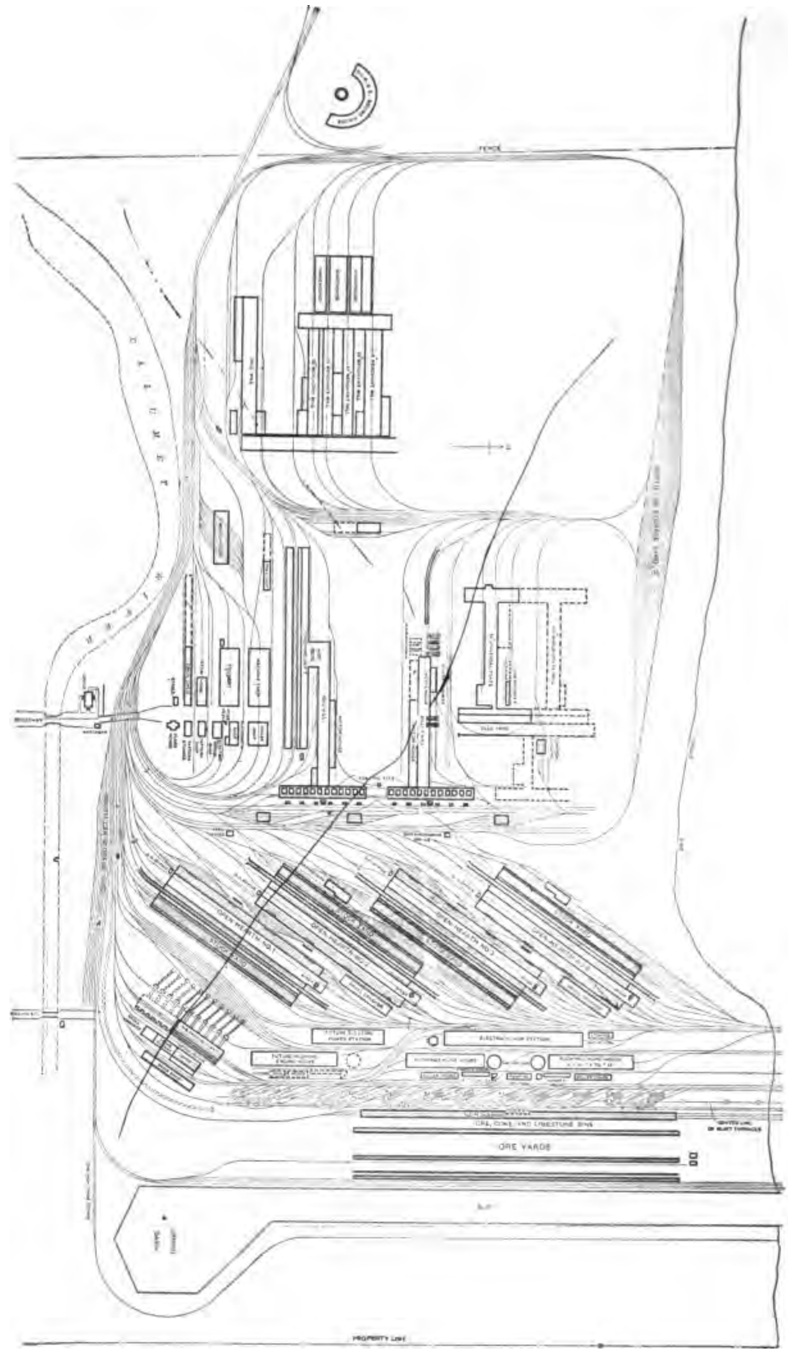


FIG. 50. GENERAL GROUND PLAN AND TRACK LAYOUT FOR THE PLANT OF THE INDIANA STEEL CO. AT GARY, IND.

plants and other auxiliary installations to be increased in the same relations as exist in the completed plant. Five new pig-casting machines will be added instead of six and instead of combining power houses nos. 1 and 4, no. 4 will be located at the north end opposite furnaces nos. 13 to 16, to be built on filled ground, and no. 1 will be located at the south end opposite furnaces nos. 1 to 4. Two additional open-hearths will be built together with a 48-inch universal plate mill, a 160-inch sheared plate mill, five merchant mills from 18 inches down to 8 inches, and an axle mill. A structural mill is a future possibility.

In addition to the task of preparing the steel plant site and erecting this immense group of buildings, all of which has been accomplished in the comparatively brief period since August, 1906, the Steel Corporation, through its subsidiaries, the Indiana Steel Co., the Gary Land Co. and the Chicago, Lake Shore & Eastern Railway, undertook the supervision and in part the actual building of the town of Gary, and a great deal of terminal railroad work. The entire property purchased by the Steel Corporation is a tract of land of about 9,000 acres, with approximately ten miles of frontage on the southern end of Lake Michigan at a distance of 25 miles from Chicago. The tract will be materially increased by the filling in of the shore line property. The building of the town of Gary has been completely described at other times, notably in *The Iron Trade Review* of November 21, 1907.

The tract of land is located on or adjacent to five railway trunk lines. The main lines of the Baltimore & Ohio Railroad and the Indiana Harbor Railroad ran directly through the mill site. It became necessary at once to enter into an agreement with these railroads whereby their lines were changed so as to run south of the mill site. This change also involved a change in the main line of the Lake Shore & Michigan Southern Railway for a distance of several miles. A great deal of clearing, grading and filling was done in connection with this work for which an adjustment of expenditures is to be made between all the companies interested. West of the plant, the C., L. S. & E. Railroad has built an immense yard known as the Kirk yards in which are 50.51 miles of a standard gage track. Within the plant 75.14 miles of track has been laid and additional grading has been completed for future tracks.

The financing of this undertaking is quite comparable with the

extent of the engineering problems in its magnitude. The total expenditure required to complete the work has been estimated at \$75,000,000. The amount expended at the end of December, 1907, was \$24,063,388.53. This amount was provided entirely from the surplus net profits of the Steel Corporation. It was expected that approximately \$18,000,000 could be expended in 1908 which would make a total outlay to date of about \$42,000,000. The first appropriation for Gary was made in 1905, amounting to \$10,000,000. To this was added \$21,500,000 in 1906 and \$18,500,000 in 1907, making a total of \$50,000,000, of which some \$8,000,000 still remains unexpended according to the estimate. The work authorized calls for the expenditure of about \$9,500,000 more than has been appropriated thus far but with \$8,000,000 still to dispose of, the official pocket-book is far from flat. It is a matter of record that of the \$28,000,000 available on Jan. 1, 1908, about \$19,000,000 was invested in marketable securities while \$7,000,000 was in cash or immediate assets of the Steel Corporation. The freedom permitted by this unhampered financial provision for the building of Gary was amply shown during the past year when erection work proceeded without interruption.

With all the boldness and far-sightedness of the project, reasonable assurance was required that there should be demand sufficient to absorb the productive capacity planned. It will be some time before the Gary open-hearths can produce much more than 1,250,000 tons of ingots a year, nor will anything like 1,000,000 tons of rails be rolled this year. The foundations for the billet mill have just been completed and at least the present year will pass before this mill is rolling on full schedule. It is maintained with regard to the units already complete and those to come that as great a proportion of operation, at the rate of most economical production, will be attained at Gary throughout each year of operation, as at any of the present manufacturing plants. To make the western market independent of the eastern mills is the function of Gary. The gradual accomplishment of this purpose will directly effect that large tonnage of rails, billets, plates and bars that is now diverted from the west to the American Steel & Wire Co. and the Carnegie Steel Co. in the east.

There is in reality little occasion for anticipating a severe disturbance, of existing market conditions in the Chicago territory

because of this new capacity. The Gary plant represents an adjustment of production within the Steel Corporation rather than new capacity seeking tonnage in the west. Rather will the eastern capacity which Gary displaces, require to be provided for, than otherwise. Attention has been directed to the large tonnage of scrap that will be consumed at the Gary open-hearth furnaces. Without forcing the situation in any respect, the percentage of scrap employed in the open-hearth charging may be brought down as low as 25 per cent. of the total. With a production of 800,000 tons of ingots during 1909, which at this time seems to be a fair prediction, only 200,000 tons of scrap will be absolutely required. This much the Chicago dealers accumulated with ease during the past year. To this may be added fully 160,000 tons of steel scrap—rail scrap ends and ingots discards—which may be expected from

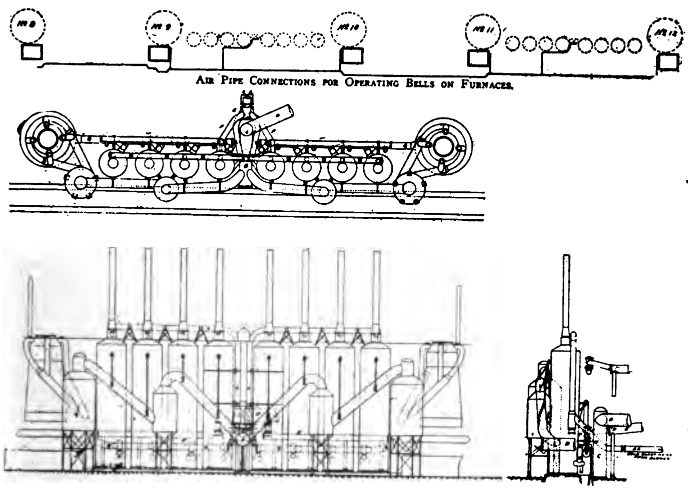


FIG. 51. LAYOUT OF FURNACES, DUST CATCHERS AND STOVES SHOWING THE GENERAL ARRANGEMENT OF THE GAS AND AIR PIPES.

the Gary plant itself. This material is of course not the best kind of steel and under ordinary circumstances purchased material of various grades will be mixed with it. When it is remembered however, that there is to be a scrap yard at Gary where material picked up in any quarter and in any condition may be handled it is apparent that little disturbance of the market will result from the buying of such tonnage as is required.

The laying out of the steel works presented itself as a railroad

switching problem and a glance at the ground plan will make it clear wherein the Gary steel plant is one of the most remarkable railroad yards in the world, Fig. 50. This plan is not quite complete and does not show how the railroad loop is to be connected along the north end of the site where the shore line property is not yet filled. When this is completed there will be a continuous connection entirely around the plant for a length of approximately eight miles. It will be possible then to have continuous travel in one direction to and from any part of the plant. All of these tracks are standard gauge. The matter of laying out the blast furnace plant, open-hearths, power plant and other departments was interwoven with the solution of the railroad problem. A general scheme was evolved in which the entire plant was divided into four blast furnaces and their auxiliaries as the basis for each unit. These units extend in parallel lines from the slip on the east to the finishing mills on the west. The present construction is concerned with the building of the two middle units from furnaces nos. 5 to 12. Units nos. 1 and 4 remain to be built on the south and north sides of the site respectively and will include furnaces nos. 1 to 4 and furnaces nos. 13 to 16. The connecting railroad spurs from one side of the loop to the other, which comprise the service tracks running through and paralleling the furnaces and various buildings have a general north and south direction while between each pair of units is a complete set of crossover tracks which provide for the generally east and west movement of the materials in process of manufacture from ore to steel.

The essential characteristics of the plant is uniformity gained through duplication, with an extremely simple arrangement as a result.

There are certain unique conditions not ordinarily attendant upon steel mill construction heretofore, which contributed to this end. There was but one kind of steel to be made. The entire project was before the engineers to plan completely before a building was located. There was here no designing by piecemeal. The plan adopted provides for the production of a larger tonnage of steel per acre of ground than at any other plant in the world. The entire steel plant site embraces about 1,000 acres, that portion of it in which the steel ingots will be made from ore yard to ingot stripper, about 300 acres. With the completed plan capable of producing

4,050,000 tons of ingots annually, a ratio of 13,500 tons of ingots per acre of ground per annum will be attained. The striking feature of the scheme by which this condensed arrangement was obtained without impairing the freedom of transportation is found in the placing of the furnace cast houses and open-hearth buildings at an angle to the north and south lines. In effect, this permitted short and easy curves, instead of wide-swinging 90-degree layouts.

To prepare the plan site was a matter of magnitude rather than of great difficulty. The property when acquired was a stretch of alternate dunes and hollows, the upper stratum of soil being a layer of fine, clean lake sand from 30 to 60 feet deep. The surface had an average height of about 20 feet above the water level in the lake

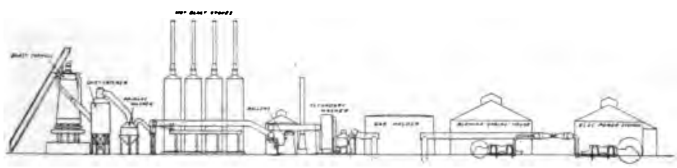


FIG. 52. DIAGRAM OF GAS DISTRIBUTION FROM THE FURNACES TO THE STOVES, BOILER HOUSES, SECONDARY WASHERS, BLOWING ENGINES AND POWER PLANT.

and rose toward the south with a slope of approximately 2 inches to 100 feet. Below the upper sand at a depth of about 30 feet below the water level is a solid stratum of hard clay. Although it was frequently necessary to go below water level, the soil conditions were very well adapted to the building of large foundations for heavy loads. In this continuous heavy bed of sand it was not necessary to go deep to bottom the footings or foundations and no special provisions were required for carrying even the heaviest structures, except where piling was driven under the concrete unloader walls as a precaution for the safety of the slip walls.

In the low swampy lands at the east end of the site the Calumet River had its mouth, its course to there being through the south end of the mill ground. The diverting of this channel for about a mile was undertaken at once, so that it is now entirely outside of the plant enclosure. At a low point leading from the lake southward into the swamps, dredging for the harbor slip[1] was begun with

[1] Complete descriptions of the plants and methods used in constructing the harbor and in handling the concrete foundations may be found in the *Engineering Record* of August 17, 1907, and November 2, 1907.

hydraulic dredges. The completed slip and turning basin required the dredging of 1,500,000 cubic yards. Between the slip and the east line of the property, space was allotted for the future installation of by-product coke ovens. This ground remains in its original condition. On the remainder of the site the principal work consisted of clearing off the scrubby trees and bushes and leveling the land to a uniform height of about 20 feet above the lake level. The leveling was to a certain extent a steam shovel proposition and the large area of the site required the movements of a large quantity of material. The filling in of the lake property and grading with cinder brought from Joliet were carried on simultaneously. Most of the leveling preceded construction work, but some of the larger building sites were excavated at the time. Although a number of the foundations extend below water level, there was no need of deep foundations. The foundations constitute a distinct feature in themselves and will be described briefly in connection with each department. All of the heavy foundations are of mass concrete and in connection with the great amount of concrete required and the construction methods employed, there is much of interest. In the unloader walls and the foundations for the power house, blowing engine house, and open-hearths, approximately 350,000 cubic yards of concrete were placed.

The completed harbor slip will be 250 feet wide, 25 feet deep and 5,000 feet long, not including the turning basin, which is 750 feet across. Of the 5,000 feet, 3,000 feet extend inland from the original shore line. The remaining 2,000 feet was dredged out into the lake, at which point the natural depth is about 25 feet. This distance represents the width of submerged property which is to be filled in along the lake side. About 1,000 feet of ground has already been made. On the west side of the slip, a massive concrete wall containing 6 cubic yards of concrete per lineal foot extends for the entire length and entirely around the turning basin. Mooring posts are located conveniently and the longest boats once in the slip can be warped to any point and out again without the assistance of a tug. To be provided with a turning basin is unusual among steel plant shipping facilities. The lake course to Gary is a straight run for the harbor.

From the face of the dock wall to the center line of the furnaces is 609 feet 3 inches. This width for a length of 4,000 feet will be occupied by the ore yards and ore bins. At present the middle half of this length has been completed.

The capacity of these ore yards exclusive of the ore bins provide for the handling and storing of 320,000 tons of ore for each furnace or what will be, very easily, ten months' supply under ordinary conditions. The ores already at the plant include group nos. 3 and 4 and Vermont ore from the Mesabi range, Chapin from the Menominee, Bernhart from the Marquette range and Vermillion lump from the Soudan mine in Minnesota, all non-Bessemer.

The ore yards are divided longitudinally by the walls on which the unloaders and bridges are carried. This permits of a complete separation of the different ores. An ore trough with a capacity of 35 tons per lineal foot extends the full length of the ore yard. Ore in transit from boat to stock pile is temporarily deposited here by the unloaders and again picked up by the bridge. The trough is V-shaped with a curved bottom to facilitate the handling of ore. To prevent the breaking up of the concrete on account of the buckets striking it, the bottom is reinforced by 75-pound steel rails.

The ore-handling equipment consists of five Hulett electrically operated, vertical steel leg type unloaders, and five Hoover & Mason ore bridges. A complete description of this unloader may be found in the *Iron Trade Review,* May 14, 1908. The unloading machines are heavier than preceding types and weigh approximately 850 tons. The bucket has a capacity of 10 tons and the unloader will average 500 tons per hour in unloading the first half of the cargo. The improvements in this machine are concerned very largely with the use of this built-up steel bucket leg and the manner of operating it. It is extremely flexible. The leg can be rotated through an angle of 320 degrees. The bucket itself is so contrived that one scoop may be telescoped to give it a reach of 15 feet 4 inches from the center line of the column. This enables fully 90 per cent. of the cargo to be unloaded without hand shoveling and in some cases as much as 97 per cent. It has a maximum reach of 53 ft. 9 ins. at a depth of 8 ft. 2 ins. below the water line or 26 ft. 10½ ins. on either side of the center line of the boat.

The span between the front and rear legs of the unloader is 62 ft. 10 ins. In this space paralleling the slip are four tracks for shipping ore from Gary to other points. Cars spotted under the unloaders can be loaded direct. The ore trough wall in which the rear end of the unloader is carried, is of solid concrete 8 ft. across the top, 20 ft. across the bottom, and 26 ft. 4¾ ins. deep. It carries 100-pound rails.

The ore bridges in order to span the 425 ft. from ore trough to ore bins, are unusually long, approximately 498 ft. over all. They are built unusually high also in order to clear the unloaders and have a clear height above the floor of the ore yards of 85 ft. The bridge buckets have a rated capacity of 15 tons. The particular feature of these bridges is the provision for swinging them through and angle of about 20 degrees or 75 ft. either way. Where convenience requires that ore be deposited at some point in the ore trough not exactly opposite the point of final storage, one rotation of the bridge through the desired angle avoids the moving of the entire bridge back and forth through the short distance necessary for each bucket load. The bridges are electrically operated and have about the same track speed as the unloaders. The movement along the track is made positive by the use of a cable and drum.

The unloaders are operated along the tracks with power from a 75-horse power motor, the hoist for raising and lowering the leg is drawn from a 150-horse power motor and the bucket car is operated by a 200-horse power motor. The ore bridges are driven by four 80-horse power, four 40-horse power and four 30-horse power motors.

The ore, limestone and coke bins are of the Brown suspension parabolic type of heavy steel construction. The ore bins have a capacity of 13 tons per lineal foot and a total capacity of 20,000 tons of ore. The coke bins have a capacity of 4 tons per lineal foot and a total capacity of 6,160 tons. The bins will hold about 9 tons of limestone per lineal foot. All of the steel members of the bins, the deck spans, connecting the bins and connecting trestles are designed with a factor of safety of five for live loads and of four for dead and wind loads. In addition to the large capacity for ore, coke and stone, the loading of which into the bins is a consideration in calculating the live load, there are on top of the bins the unusual number of four standard gage tracks. These are spread 6 ft. 6 ins. between centers. Three tracks are used for standard railroad equipment service in the delivery of coke and stone. The fourth is used for transferring ore from the ore bridges to the bins in 60-ton transfer cars. It is apparent that unusually heavy concrete foundations and steel constructions were required. The foundations are of mass concrete and contain about 10 cubic yards of concrete per lineal foot. The supporting trestle is built of heavy structural steel

columns carrying heavy plate girders. The span of the girders from center line to center line of columns is 31 ft. ½ in.

The completed bins are arranged in three sections separated by two trestles, one 364 ft. 9 ins. long, and the other 279 ft. 4 ins. long. One section consists of two ore and two coke bins 112 ft. 8 ins. long; the second section consists of one ore bin and one coke bin 197 ft. 2 ins. long, and the third section consists of four ore bins and four coke bins 281 ft. 8 ins. long. The total length of the bins from center to center of end bents is 2,192 ft. 8 ins. The bins are arranged in panels of which there are 110 in all, each 14 ft. 1 in. long. All of the ore panels are uniform. All of the coke panels are also, except for a large central coke bin installed opposite each furnace for the direct discharge of the coke to the skip. This bin has a capacity of 270 tons of coke. Each of these bins is equipped with an electrically operated bottom gate which is controlled by the operator of the skip hoist. The purpose of the bin is twofold. With 12 hours' supply of coke directly available, the charging of coke into the stack can be made temporarily independent of the operation of the larry cars using the bins. But one handling is required for the coke which is taken from the large bins as compared with two from the others. This is considered to be a large factor in fuel cost.

Each panel length of ore and limestone bins is equipped with two bottom spouts and gates and each coke bin panel with one spout and gate. The driving shaft and gearing for operating the gates are hung from the bottom of the bin. The opening of the gate is controlled from the larry operating in the tunnel beneath the bins. The ore bin trestle will slope down to ground level at both ends, eventually, and be a part of the loop system. Between furnaces nos. 10 and 11 are the crossover switches for the ore bin tracks and at these points there are no bins for a distance corresponding to the length of the trestle sections mentioned above.

Two transfer cars operate on top of the ore bins. Into them the ore is discharged from the bridge buckets carried to whatever bin is desired. These cars consist of a side dump steel hopper with three doors and a capacity of 120,000 pounds of ore. These hoppers are mounted on trucks of M.C.B. specifications. The car is electrically operated in every particular, including the mechanism for opening and closing the doors. It is equipped with two 50-horsepower motors hung from the main axles and current is taken from

a trolley attached to the bins. The trolley connection permits of shifting the transfer car to any of the four tracks. The traveling speed of the cars is about 600 feet a minute when loaded, and 900 feet a minute when light. The car carries one operator. The subway beneath the bins is unusually light and commodious. It is enclosed in permanent brick walls throughout its entire length. Windows are placed at intervals of a very few feet. In this tunnel ten electric larries are operated in transferring materials from the bins to skip cars. These larries have buckets of 120 cu. ft. capacity which are carried on a special weighting mechanism. The balance levers are directly in front of the driver so that he may readily watch the quantity taken from the bin. The larry is electrically driven by a 21-horsepower car motor through a train of gearing. Current is taken from an overhead trolley. The traveling speed with a full load is from 600 to 900 ft. a minute. Another 21-horsepower motor is installed on the larry for operating the foot gates of the bins and each motor has a separate controler. Projecting down from each bin gate is a key through which a mechanical connection is made between the larry motor and the gearing above. A socket, located on the larry, may be raised or lowered by levers from the driver's position on the larry to fit over this key so that one man on each larry controls the complete transfer of material without moving from his position.

The details of design and the kind of auxiliary apparatus to be used with the blast furnace plant were worked out to a great extent at Pittsburg and South Chicago before the Gary plant was built. The arrangement of 16 stacks in one straight line with an absolutely uniform layout is unique and is even spectacular, with but eight furnaces erected. The advantages of the layout have already been mentioned.

In order to excavate for the foundations of the furnaces, stoves and ore bins, and in order to build the skip pit it was necessary to drive sheet piling to hold back the sand and some of the water. The site of no. 12 stack, upon which the first work was begun, is on the original shore line. The foundation work progressed from this point southward. The form of skip pit used here—a steel shell lined with brick—was first used at South Chicago. The construction was found desirable below water level, the bottom of the skip pit being 4 ft. 3 ins. below datum. In order to decrease this depth as much

as possible the incline of the skip runway just above the pit was changed from 60 to 45 degrees, putting a curve in the tracks.

The concrete pier under the stack has an outside diameter of 56 ft. and is 22 ft. 1½ ins. deep below the hearth bottom. The inner pier on which the hearth is built is 40 feet diameter and the top is at a height of about 24 ft. 1½ ins. above datum or 4 ft. 1½ ins. above ground level. Upon this 9 ft. of brick is laid for the hearth bottom, the concrete being carried up around the brick for a height of 3 ft. 4 ins. The outside of the pier is carried up as an enclosing wall to a height of 35 ft., from which the furnace level slopes up to a point 1 ft. 8 ins. above the iron notch or to a height of 17 ft. 8 ins. above ground level for the floor around the stack.

The center line of the piers for the cast house is parallel to the center line of the iron notch which is at an angle of 22½ degrees to the north and south line on which the stacks are laid out. The cast house center line is offset 8 ft. 6 ins. from the iron notch. The two arched concrete piers are 9 ft. 6 ins. across the top, 81 ft. 6 ins. long and have a slope on top of 1 ft. in 12. Between the piers is a space about 17 ft. wide. Into this a track is laid for the hot metal ladles. On the opposite sides of the piers the slag and auxiliary hot metal are delivered. There are three hot metal spouts delivering to the center track, three slag spouts to the outside track and two auxiliary hot metal spouts to the inside track. The hot metal and slag trains will be made up of three 40-ton ladle cars. The construction of the cast house is what might be called a skeleton type.

In the design of the stack proper no innovations have been attempted. The shell is noticeably heavy for a 450-ton stack and the banding of the boshes is much more secure than ordinary circumstances would require. There are in all 15 steel bands 1½ × 8 ins. There are seven rows of cooling plates in the boshes, one row for the tuyeres and cooling plates for the iron notch. These cooling plates are 27 ins. deep and extend entirely through the walls. The brick lining of both hearth and boshes is 27 ins. thick.

The hearth is 15 ft. diameter, the depth from tuyere to cinder notch 3 ft. and from cinder notch to iron notch, 4 ft. From the center line of the tuyeres to the top of the crucible is 2 ft. and the total depth of the crucible is about 10 ft. On the basis of 6,000 pounds of coke consumed per square foot of hearth area and assuming a consumption of 2,200 pounds of coke per ton of iron. these

furnaces have hearth capacity for the production of 530 tons every 24 hours. Allowing 3 cu. ft. of crucible capacity per ton of iron made, the furnaces have a capacity of about 580 tons daily. It is apparent from both estimates therefore that the rated capacity of 450 tons is very conservative. The fact that it is expected to tap the furnace every four hours adds to the possibility of driving the stacks for a much larger production. The tuyere capacity also provides for this greater production. There are 12 tuyeres whose openings can be varied from 4 to 7 ins. The maximum opening would give a total area of tuyere opening of 461.76 sq. ins. which would provide 46,176 cu. ft. of air at the rate of 100 cu. ft. of piston displacement per minute. An average requirement for a 15-ft. hearth is 40,600 cu. ft. The bustle pipe has an area of about 1,018 sq. ins.

The boshes are 13 ft. high and the bosh diameter is 21 ft. 6 ins. This is according to standard practice both as to the batter of the bosh walls and the relative area at the bosh and hearth. The height of the inwalls is 40 ft. and the inside diameter at the top is 16 ft. From the top of the inwalls the shell is cylindrical for a height of 11 ft. 10 ins., above which there is a dome top of ⅞-in. plates shaped to a radius of 12 ft. 6 ins. The total height of the stack from the center line of the iron notch to the top is 88 ft.

The hearth has a double jacket. The inner or cooling jacket is three inches thick and is built of cast iron, in 22 sections. The embedded cooling pipes are extra heavy 1¼ in. wrought iron pipe. The outer jacket is built in 12 segments, of steel castings 5 ins. thick, bound together by steel bands which are continued around the circumference of the hearth and by steel links shrunk on to the solid lugs cast with the segments. A cooling gutter extends all around this outer jacket below the floor line. The water trough which acts as a header for all the cooling water circulation around the boshes and the hearth has a double compartment. The lower compartment is enclosed by a false bottom for the upper gutter and receives the water under pressure from the central pumping station. The circulating pipes are taken off of this compartment and returning, the water flows into the upper gutter. From here it runs by gravity to the primary washers, the bosh water being used for these washers entirely.

The mantle of the furnace is carried on eight cast iron columns

27 ft. 11½ ins. long. Although this is an unusual height for cast iron columns, structural columns being preferred usually for more than 18-ft. lengths, cast iron columns have been used very successfully at South Chicago. They are of better shape than built up columns and offer greater resistance to wear and tear. They are jacketed at the bottom to protect them in case of break outs. The cast columns are made very heavy and are designed to carry a load of 750,000 pounds with a factor of safety of about 15.

The top of the furnace is of standard design for closed top operation. It is equipped with a Baker-Neumann distributor. The skip bridge is heavy construction. The weight of the skip is carried by the ore bin foundation and the stack, but the steep angle of incline and the arrangement of the link by which the upper end is carried makes the weight component on the stack small, and in direction, causes it to fall within the center line of the furnace so that there is no overturning moment. The skips are operated in balance by an Otis Elevator motor-driving hoist. The hoist house is located under the bridge, but the controller for the hoist motor is in the operator's cage just above the skip pit. From this cage the skip operator controls the skip operation, the large coke bins and also the stock line test rods. The operator is also provided with a 4-light signal, showing in which quadrant of the stack the distributor will place the next load. In this way the entire charging of the stack is under the direct observation and control of one man.

The cylinders for operating the bells are located in the hoist house. They are pneumatic cylinders operating on 10 pounds per square inch pressure. The air for operating is taken from the cold blast main and connection is made, continuous for all of the furnaces, so that with but one stack in blast the bells of all the stacks may be raised or lowered.

A description of the blowing engines and the calculations connected with the use of the blast furnace gas for power, will not be attempted in this chapter. The course of the gas through the stoves and washing plant involves comparatively few new features.

The gases pass off from the furnace through four branches which finally unite in two downcomers 5 ft. 6 ins. diameter. The gas connection is made through a heavy 130-degree elbow, taken off of the dome at an angle of 51 degrees and 15 minutes from the vertical. The gases in the downcomer have a velocity of about 20 ft. per

second and discharge into the bottom of the first dust catcher in the usual manner for producing a whirling motion of the gases. This dust catcher is 30 ft. in diameter and 40 ft. high. The gas passes out of the top and down through a main 7 ft. 3 ins. in diameter to a second dust catcher 14 ft. diameter by 25 ft. high.

The dust catchers are placed as close to the stoves as possible, the distance from center to center line being only 15 ft. 6 in. Inasmuch as the gas from both stacks passes from the second dust catcher into a common 10-ft. main, the dust catcher is converted into a water valve when one stack is off and acts as check valve.

The gas goes from the dust catchers to the primary washers. These are arranged in groups of three for each pair of furnaces. One washer takes care of all of the gas from one stack, the third washer being thrown in while one of the others is being cleaned. These washers are a modification of the Mullin type. In the Mullin washer, the gases are discharged against the surface of the water through tubes. The course of the gas and the principle of cleaning is the same in the Gary primary washers, except that a funnel is used instead of a cylindrical tube to bring the gases down, and instead of tubes the lateral surface of the funnel is deeply fluted. The gas immediately expands at the top of the funnel into these convolutions and is broken up in the same degree as where tubes are used and at the same time without the possibility of the gas being clogged with dust.

A track runs directly under the washers so that they may be cleaned directly into a car. Concrete draining basins are built around the track from which the water runs off into settling basins 5 ft. 9 in. deep by 7 ft. by 20 ft. The gas, in passing through the primary washers is only cooled from 100 to 150° and should have a temperature of about 400° Fahr. on returning to the stoves.

The gas is divided after leaving the primary washers, about 30 per cent. or a little less proceeding to the stoves and the remainder passing over to be again divided, about 7.5 per cent. to the boilers and the remainder to the Zschocke washers. There are four stoves for each stack. They are of the improved McClure type, 22 ft. in diameter by 95 ft. high having a total heating surface of about 200,000 sq. ft. The stoves are mounted on rails of 80-pound section which provides for such expansion at the bottom as may take place. A quick opening snort valve has been put on these stoves. It is an adaptation of the by-pass valve and can be operated very quickly

by means of a lever instead of a hand wheel. Provision is made for renewing the chimney valve and seat more readily than formerly by supporting the chimney on four struts, one of which is so designed that it can be removed, permitting independent access to the valve. A feature of the stoves and furnaces also is the unusually ample stairway and platform facilities and the placing of hand rails at all hazardous places.

The secondary washing of the gas is accomplished in a series arrangement of Zschocke and Theisen washers. Both of these washers are familiar types. The Zschocke washers are vertical cylinders 14 ft. in diameter and 50 ft. high. The upper half is filled with a pile of horizontal grids through which the water passes downward and the gas upward. The lower half is filled with umbrella-shaped baffle plates which are in series with the grids above. This arrangement is a modification of the methods used at Edgar Thomson only in that the grids and baffles are in separate washers each about 25 ft. high. The gas goes directly from the Zschocke to the Theisen washers. There are eight of each kind. The velocity of the gas has been reduced by this time to not more than 3 or 4 ft. a second. It is forced into the Theisen washer, which revolves at 850 revolutions a minute, and is thrown against a film of water. The purification is complete to the extent of leaving approximately 0.01 grain of solid matter per cubic foot of gas. The requirement of cleanliness for gases to be used in gas engines is about 0.1 grain of solid matter per cu. ft. of gas. The Theisen washers are driven direct by 150-horsepower motors. Current is obtained through three water and oil cooled 6,600/440-volt transformers. Average practice has shown that for each 1,000 cu. ft. of gas the costs of the Theisen washer are as follows: Installation, $23; water consumption, 9 gallons; power consumed, 0.15 horsepower; operating expenses, 3.8 cents.

The gas from the Theisen washers is delivered to two gas holders, 90 ft. diameter with 30 ft. of travel and a capacity of approximately 200,000 cu. ft. The water from the washers drains into a large concrete settling basin.

Ordinarily the movement of hot metal will be directly to the mixers in the open-hearth building. On other occasions when a part or all of it is not required at the open hearths it is diverted to the pig casting plant. Similarly with the slag, which will ordinarily be run into ladles and used for filling, provision has been made for granulating the cinder whenever desired. Between each pair of

furnaces, alternating with the primary washers, is a granulating tank 154 ft. long by 17 ft. wide by 22 ft. deep and built of concrete. The cinder is granulated by a stream of water directed against it as it falls from the slag runner into the tank.

The pig casting plant is undoubtedly the most advanced type thus far designed. As regards capacity, it is intended to be capable of handling the entire output of the furnaces, as it will be called upon to do regularly when the open hearths are off. In the matter of lay-out, the chief consideration has been independence and freedom of operation, both for the handling of the hot metal ladles and in loading the pigs. The plant consists of a cast house six two-strand

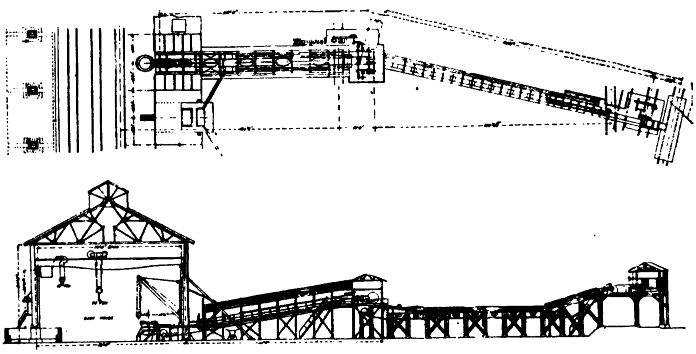


FIG. 53. CROSS SECTION THROUGH PIG CASTING PLANT.

Uehling pig machines with cooling conveyors, a ladle repair house, skull cracker and scrap yard.

The cast house is 82 ft. wide by 393 ft. long, with a clear height under the trusses of 54 ft. The building can be extended 300 ft. to the south to accommodate five additional pig machines. Two 75-ton cranes with 15-ton auxiliaries span the building, in addition to which a 10-ton repair crane is installed. On the east side of the cast house a cleaning platform 15 ft. wide extends the full length of the building. On the opposite side are the pouring troughs. Between, three ladle tracks with cross-overs run through the building on the ground level.

The pig machines are of a standard type and are 115 ft. long. Each machine discharges to a cooling conveyor having a tank 99 ft. long. The pigs are conveyed through this tank, submerged in water before being discharged into the cars. The machines and conveyors are set at an angle so that an arrangement of the loading tracks has

been possible whereby each conveyor discharges upon its own individual track quite independently of the other machines. The loading tracks constitute a gravity yard so that cars may be fed down from the main track by gravity on a 1.25 per cent. grade. There is room for the storage of seven cars on each of these tracks.

The pig machines are driven by 40-horsepower induction motors and the cooling conveyors by motors of 30 horsepower.

The method of pouring the hot metal into the pouring trough is unique. It may be termed lip pouring as contrasted with other methods where the ladle turns about its trunnions in pouring and begins to spill the metal when the lip is still several feet above the pouring pot and ends with the lip practically in contact with the pouring pot. The loss of metal from splashing is considerable under such conditions. To avoid this wasteful splashing the ladle is set in a pouring cradle which is pivoted at a point directly under the lip of the ladle. This entire cradle is then lifted in such a manner that the ladle practically turns about the end of the lip as a center, with the result that at every stage of the pouring the hot metal falls through a nearly constant and a minimum distance. The pouring device consists of a ladle stand directly in front of each pig machine. This stand comprises two upright frames at the upper ends of which are pivoted the ladle cradles. The lower ends of the cradle are tied together by a cross-head to which attachment is made for tilting. When not being tilted the bottom ends of the cradle rest on the stand.

The cradles are tilted by means of jib cranes which swing out over the ladles from the wall. To protect the boom of the crane from the heat of the metal in the ladle it is faced with asbestos. The crane is operated by a motor-driven hoist at one side. After a ladle is poured, it is picked up from the cradle by the over-head crane, by means of which it is also lifted from its truck when first brought to the cast house and placed in the pouring cradle. It is carried to the cleaning floor where it is cleaned and the lip relined. It is then again picked up and returned to its own tracks.

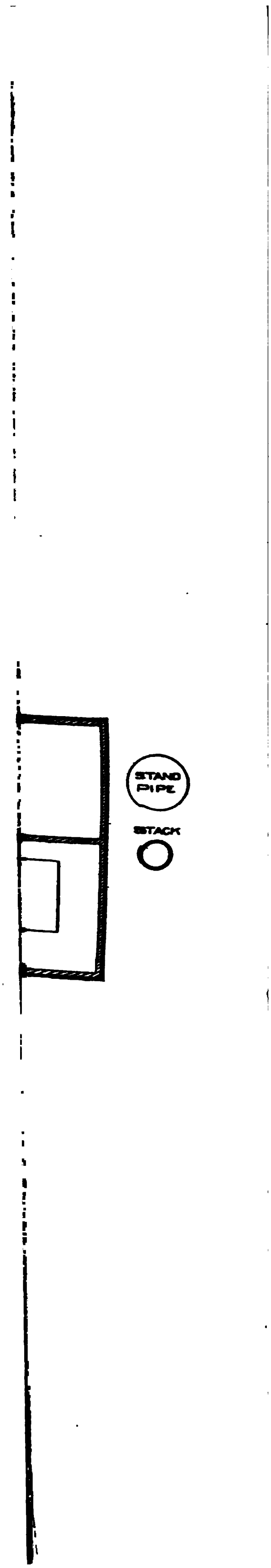
The ladle repair shop, scrap yards and skull cracker are arranged in a row with the runaway on which a 50-ton crane is operated, extending through all three continuously for a length of 460 ft. This runaway has a span of 75 ft. which is the common width of the three departments and a height to the top of the rail of 32 ft. 6 in.

The crane has a 15-ton auxiliary, and is used both for lifting and pulling the ladle trucks and scrap cars along the surface tracks.

The ladle repair house is 200 ft. long and in addition to the main floor under the crane it has a 30-ft. lean-to for the storage and mixing room and a tool room and repair shop.

Two ladle tracks traverse the building entering from the north end. A spur track also runs into the building on which trucks are repaired and from the opposite end a track for the removal of scrap leads out through the scrap yard and skull cracker. Six ladle dryers are arranged along one side of the building. These dryers consist of a ladle stand and an installation of gas burners arranged with a hood to project a heating and drying flame against the ladle lining. The gas for these burners is generated in a gas producer located in the building. In front of the brick shed storage are four relining pits.

The scrap yard is a storage space 120 ft. long and 75 ft. wide surmounted by a framework for carrying the crane runway, and traversed by the scrap track. The skull cracker consists of a skeleton frame work 100 ft. long 79 ft. 6 in. wide and 70 ft. high to the bottom of the top bracing. This framework also carries a 40-ton crane, the runway for which is 27 ft. 6 ins. above the 50-ton crane, and has a span of 77 ft. 6 ins. The 40-ton crane has a 10-ton auxiliary. The total height of the runway of the top crane is 60 ft. This crane will be provided with an electric lifting magnet.


STAND PIPE
STACK

CHAPTER V.

THE LAYOUT, DESIGN AND CONSTRUCTION OF COKE PLANTS (AMMONIA AND BENZOL RECOVERY).

The general arrangement of a plant of 100 United Otto ovens made with a view to subsequent extension to 150 or 200 ovens, is shown in Figs. 54 and 55 in plan and cross-section. The ovens are to be ultimately arranged in four 50-oven batteries all in one row, the condensing house and auxiliary apparatus being placed on the pusher side opposite the initial 100 ovens. Between these two batteries and the two future batteries is placed the coal bin, which is designed to supply all four.

On the discharge side of the ovens are the coke-quenching car, the coke tracks, the coal-receiving tracks and the coal-handling apparatus; either the inclined quenching car or the Moore Type of quencher may be used, both being shown. Adjacent to the coal-receiving hoppers the storage of coal on the ground level may be provided for, if desired.

The gas-collecting mains of both pairs of batteries lead towards the coal bin, and cross there to the condensing house. This is so arranged that the gas enters at one end and leaves at the other, passing successively through the various operations in their prescribed order. The pump room, liquor cisterns and gas holder are located close to the condensing house, while, forming practically an extension to it, are the ammonia house, the power house, shops, etc.

Railroad tracks are provided for sulphate shipment and for shipment of tar, the tar and liquor storage tanks being located along the last-mentioned track. A separate track raised on a trestle supplies fuel to the boilers.

The office and laboratory building is located near both condensing house and oven batteries for convenience of access. This general arrangement may be said to provide for the initial installation in a compact and convenient manner, while admitting of extension without sacrifice of future efficiency. It is easily accessible for railroad tracks without long approach curves, and gives ample facilities for rapid switching and coal storage.

Furthermore, by avoiding isolated buildings it saves a portion of

the construction cost. Lastly, it preserves, as far as possible, the existing ground level without expensive filling in, and with a minimum amount of foundation work.

The arrangement of the condensing and ammonia houses for 100 ovens, with the extension to 200 provided for, is shown in Fig. 54. As will be seen, the original building is made large enough to inclose all the by-product apparatus, power plant, etc., needed for the ultimate extension, with the exception of the gas coolers, for which an addition may be constructed. The additional machinery, storage tanks and other apparatus and their location are shown by dotted lines. Provision is made for handling two qualities of gas for

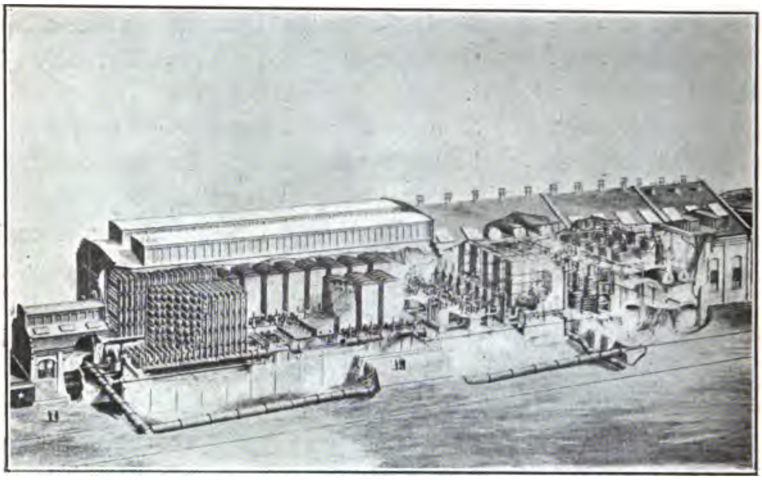


FIG. 57. SECTIONAL VIEW OF CONDENSING HOUSE OF LACKAWANNA STEEL CO.

benzol transfer from the poor to the rich gas, and for the necessary auxiliary power plant, but otherwise the plant is similar to that shown in the sectional view (Fig. 57).

The details of a United Otto by-product oven are shown in the cross section in Fig. 58, which also gives the arrangement of the coal conveyors, coal bin, pusher and quencher. The oven itself is a rectangular retort from 33 ft. to 43 ft. long, 7 to 9 ft. high and 17 ins. average width, with or without taper, the dimensions varying with the characteristics of the coal that is to be used. The retort walls, top and bottom are composed of refractory material, and the masonry is supported on a steel or concrete substructure so as to be entirely independent of the regenerative chambers below. This

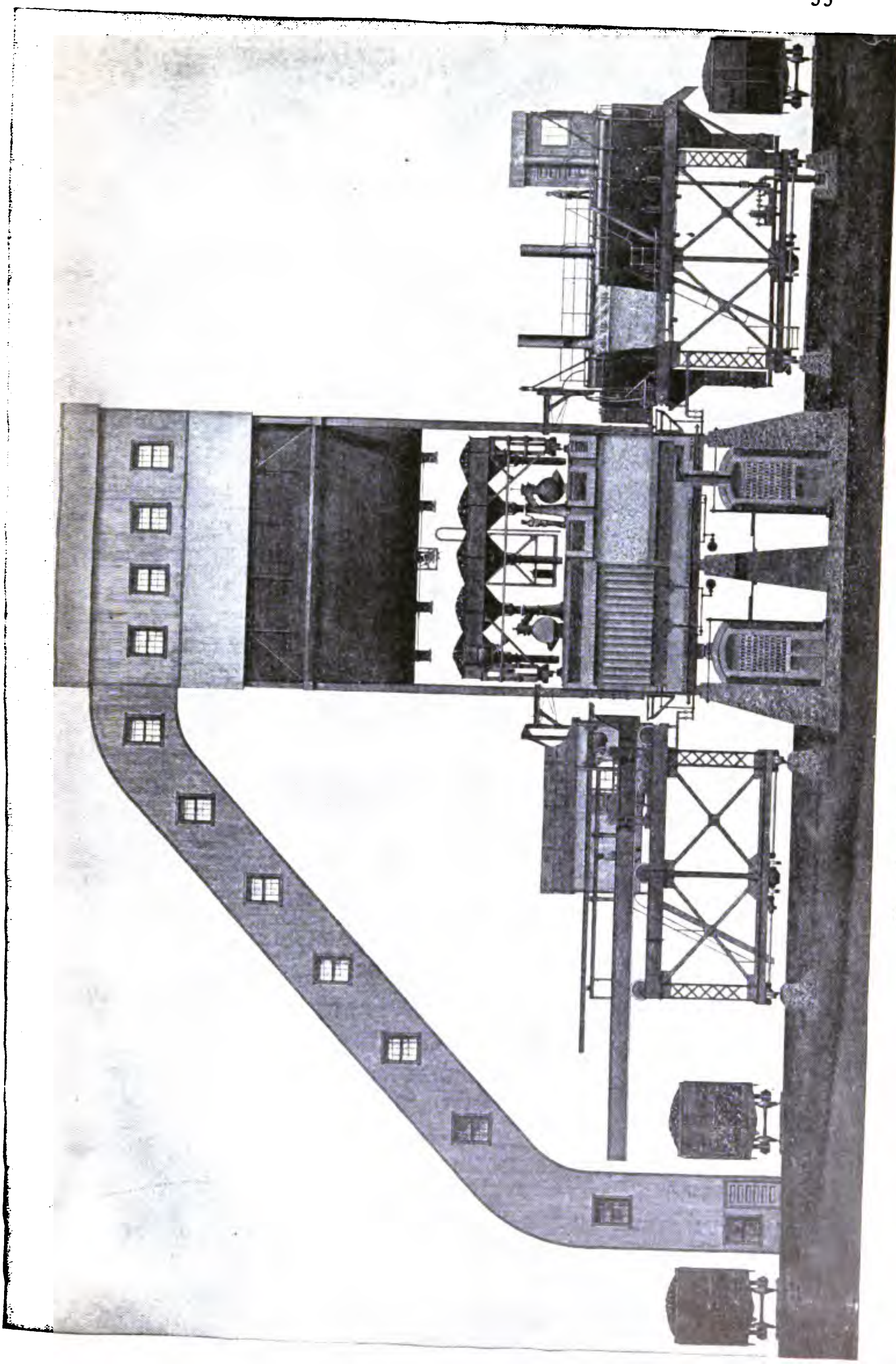


Fig. 58. The United Otto By-Product Oven.

avoids the cracking of the oven walls and the consequent loss of gas, liable to occur from the expansion and contraction of the heated regenerator walls beneath the oven structure. Access is also given to all parts of the oven for inspection and incidental repairs. The open substructure admits of a complete anchoring system joining the buckstays above and below, and holding the oven walls securely in place. The steel work of the substructure is properly protected from the heated brick work above, this protection also serving to retain the heat in the ovens themselves. The oven chamber is closed at either end by doors.

General Arrangement.—A sectional view of a condensing house and apparatus is shown in Fig. 57, the general arrangement being similar to that built at the by-product coke oven plant of the Lack-

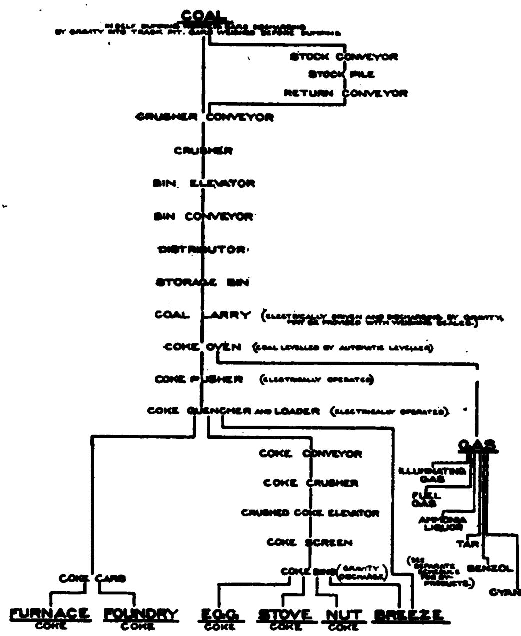


FIG. 59. SCHEDULE SHOWING MECHANICAL HANDLING OF COAL AND COKE IN BY-PRODUCT OVENS.

awanna Steel Company, at Buffalo, N. Y. The arrangement here adapted lends itself well to the general design of a plant where future extensions must be provided for, without sacrifice of convenience or economy in the immediate installation. The course of the gas is in general from one end of the system to the other,

through a number of units working in parallel with conveniently arranged by-passes. This design simplifies the separation of the rich and fuel gases, if the production of illuminating gas is desired, and at the same time allows extension on either side to take care of additional oven capacity.

Schedule showing Mechanical Handling of Coal and Coke in By-product Ovens.—The sequence of the mechanical operations through which the raw coal and the resulting coke pass in a modern by-product coking plant is outlined in the diagram Fig. 59.

Gas.

Treatment of Gas.—The gas given off from the coal during the coking operation is led away from the oven through up-take pipes, furnished with valves, to the gas-collecting mains. If the surplus gas is to be used for fuel purposes, only one gas-collecting main is needed, but if it is required to make illuminating gas two are used, the additional one to take the portion of the gas delivered during

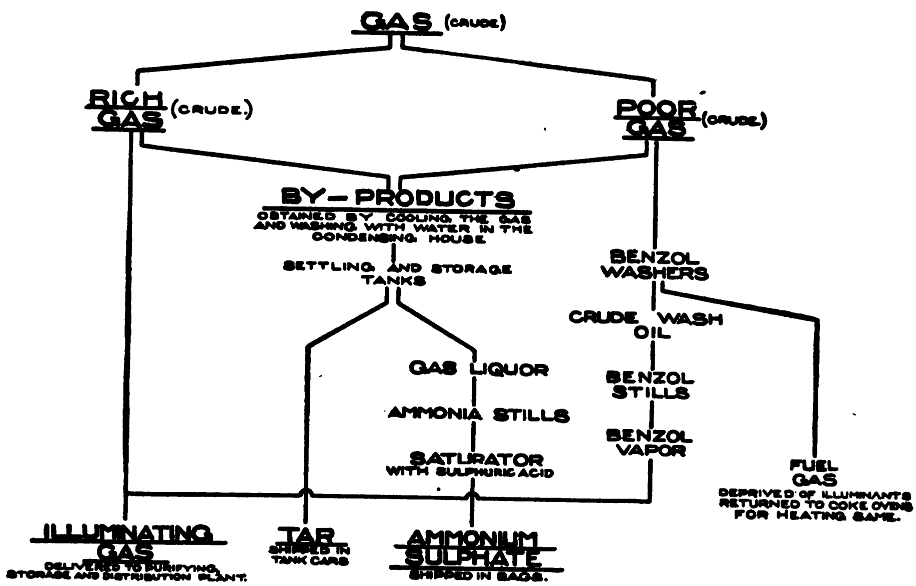


FIG. 60. SCHEDULE SHOWING TREATMENT OF GAS AND BY-PRODUCTS WITH GAS SEPARATION AND BENZOL TRANSFER.

the first part of the coking time, known as the rich gas. This fraction is higher in calorific and illuminating value than the last portion of the gas, and is therefore better suited for distribution pur-

poses. The last portion of the gas is led off into the fuel gas mains and after being freed of tar and ammonia is used for heating the ovens. The two portions of the gas are kept absolutely separate through the subsequent cooling and condensing operations, the condensing house being so arranged as to handle them in separate systems usually arranged in parallel.

The general scheme of handling the gas, and the disposition of the products resulting from it, is shown in the accompanying schedule (Fig. 60).

Apparatus for Sulphate.—The apparatus for making sulphate is shown in Fig. 61. Part of the ammonia exists in volatile form, and can be driven off by passing steam through the liquor. The remainder exists in forms known as "fixed" and must be decomposed by the action of lime or other alkali, before becoming volatile.

In the apparatus shown, the weak liquor enters the preheater *C* from feed tank *A*, to which it is pumped from the condensing house cisterns, and passing down through the column *D*, encounters an ascending current of steam, with which it is brought in intimate contact by the baffles and seals in each section of *D*. The volatile ammonia is liberated in this process, and passes, together with a certain amount of water vapor, to the preheater *C*, where it heats the incoming feed liquor, and to the cooler *B* where the temperature is further reduced, if necessary, by cold water circulation. The liquor containing only the fixed ammonia salts passes downwards to the liming chamber *E*, into which milk of lime is pumped at *e*. The reaction at this point may be expressed as follows:

$$\text{Lime} + \text{Ammonium Chloride} = \text{Calcium Chloride} + \text{Water} + \text{Ammonia.}$$
$$Ca(OH)_2 + 2(NH_4)Cl = CaCl_2 + 2H_2O + 2NH_3.$$

From *E* the liquor enters the column *F*, which is known as the "fixed" or "lime" still. Here it is again acted upon by the steam entering *F* at the steam inlet *d*. The liquor escapes from *F* at the waste cock *c*. The steam for the distillation enters the system at the base of the fixed still *F* and of the lime chamber *E* at *b*.

The ammonia vapors, together with the volatile impurities (carbonic acid, hydrogen sulphide, etc.), leaving the cooler *B*, pass through the pipe *a* to the saturators *F*, in which there is dilute sulphuric acid. The reaction here, which is attended with the evolution of considerable heat, is as follows:

$$\text{Ammonia} + \text{Sulphuric Acid} = \text{Ammonium Sulphate.}$$
$$2NH_3 + H_2SO_4 = (NH_4)_2SO_4.$$

POOR GAS FROM OVENS
RICH GAS FROM OVENS

The saturators and all the parts coming in contact with the acid are protected by lead. A discharge opening is furnished from *G* to the cooling tank *H* placed below, which is also lead-lined. As the neutralization of the acid proceeds, the sulphate crystallizes out in the form of a white salt. When the neutralization is nearly or quite complete, the process is stopped, as to continue beyond this point causes loss of ammonia and discoloration of the salt.

The salt and the mother liquor in *G* are then dropped into *H*, where they are cooled and the salt allowed to settle and drain. The mother liquor is drawn off to the well *L* for use in further saturation, and the salt is dumped into the centrifugal machine *J* where it is dried. The dried sulphate is then transported by the car *K* to the storage room, or to a machine for automatically weighing it and placing it in bags. The waste gases not absorbed by the acid in the saturators are of a very offensive nature and may be drawn off through a pipe connection to the fuel mains and burned under the ovens, or disposed of in some other suitable way.

Gas Enrichment by Transfer.

When the rich fraction of the gas is to be used for illuminating purposes, the removal of the benzol is clearly a detriment. It is, however, possible to obtain considerable benzol from the fuel gas fraction, the loss in heating power being negligible. The transfer of this benzol to the rich gas fraction for its further enrichment is carried out by The United Coke & Gas Co. This is done without the separation and condensation of the benzol, the vapors being absorbed directly by the illuminating gas.

The apparatus for the above operation forms a part of the condensing house. The general arrangement of such a plant is shown in the diagram (Fig. 62).

The process of enrichment by benzol transfer is much less difficult than it is to produce a condensed and rectified liquid benzol, which must be subsequently vaporized in the gas. The simplicity of the operation and the fact that it makes use of the supply of benzol immediately at hand are greatly to its advantage.

CHAPTER VI.

THE LAYOUT, DESIGN AND CONSTRUCTION OF CYANIDE PLANTS.

THE GOLDFIELD CONSOLIDATED MINES COMPANY'S NEW 600-TON MILL (1909).

Mill Site and Design.—The mill site lies on the west slope of the foothills at the base of Columbia Mountain, near the Sandstorm claims, which was the first mining claim located in the Goldfield camp. The company's mines are about a mile and a half southeast of the mill.

The design of the mill was carried out by Mr. Mackenzie and his staff. Francis L. Bosque, metallurgical engineer for the company, is responsible for the cyanide end, and Grant B. Shipley, engineer of Allis-Chalmers Company, designed the mechanical details of the entire plant.

Concrete Plant.—On the very top of the hill, at the millsite, was placed the rock-crushing plant for concrete to be used in the construction of the mill. This consists of a no. 3 D Gates gyratory breaker, from which the rock is carried by a steel flight-bucket elevator to a 48×84-in. revolving screen, that runs 21 r.p.m., and is set with a pitch of 1¾ ins. per ft. The oversize from this screen goes directly to the bin below, while the material which passes through discharges to a set of 26×15-in. style A Allis-Chalmers rolls set directly underneath. The fine product from these rolls goes to a second compartment of the storage bin. This rock crushing plant is driven by a 75-h.p. Allis-Chalmers motor.

The rock for the concrete work is quarried from the ledges outcropping nearby, and is largely a silicified rhyolite and a fine-grained granite, both of which are extremely hard and sharp and make excellent rock for the purpose. The product from the crusher will pass a 2¼-in. ring. The fine product from the rolls is used as sand in the mixture.

The rock and sand is drawn from the bin through standard rack-and-pinion, ore-bin gates into Sterling concrete buggies on the mixing platform, which dump into the hopper of the half-yard no. 2

Ransome concrete mixer. This mixer is driven by a 10-h.p. Allis-Chalmers motor. Buggies receive the mixture from the mixer and dump into a chute a few feet directly in front, where it falls into a skip car just underneath the platform. This skip, which is one of two on an inclined gravity tram, lowers the concrete to the wall that is being poured. The gravity tram is on the center line of the mill, the shortest wall of which, at the battery terrace, is 210 ft. long, and the longest wall, in the cyanide department, is 294 ft. long. In all there are 12 walls and rows of foundation piers exclusive of the piers for machinery.

In mixing the concrete a full buggy of rock is dumped into the mixer, then two sacks of Ideal Portland cement, then a full buggy of sand, and last, six buckets of water. In a climate so dry as this, considerable water has to be used, and the poured walls are covered with sacks and are kept wet for a couple of days.

The Ore Crushing Plant.—The ore from the mines will be brought in a train of four 50-ton, hopper-bottom, dump cars and dumped into the bin directly underneath the track. This bin is 19 ft. 10 ins. wide, 20 ft. high and 44 ft. 2 ins. long; it has an approximate capacity of 850 tons, and is built entirely of timber resting upon concrete foundations. The ore is drawn out through three 30×36-in. standard rack-and-pinion, ore-bin gates on the front side, into three large shaking feeders, each with a variable stroke from zero to 6 ins., making 100 to 125 r.p.m. Each will have a separate clutch, so that they can be operated independently. These feeders are driven by a 12-in. five-ply Giant rubber belt from the main crusher shaft.

The ore feeds into a 7½ style K Gates gyratory breaker which runs 350 r.p.m., and makes a product all of which will pass a 2½-in. ring. This product falls directly into a Gates screen 48 ins. in diameter and 14 ft. long. The screen plate, which is of manganese steel ¾ in. thick, has 1½-in. round holes. The product through the screen, which will be 1¼-in. and smaller, falls directly into a hopper feeding upon the inclined belt conveyor below. The oversize goes to two no. 4 special short-head, style K Gates gyratory breakers, the product from which also falls upon the inclined belt conveyor underneath.

The crusher plant is driven by a 150-h.p. Allis-Chalmers belted motor running 570 r.p.m. The main line shaft is $5\frac{15}{16}$ ins. and

$4\frac{7}{16}$ ins. in diameter, and the motor belt is a 26-in. endless double leather belt. All other belting is Giant rubber belt.

Fig. 63. End Elevation of Cyanide Mill.

The crusher building is entirely of timber construction on concrete foundations, and is closed in and roofed with asbestos-covered

corrugated metal. The crusher plant has a capacity of 600 tons in eight hours.

The ore from the three gyratory breakers falls upon the belt of a 26-in. trough-inclined belt conveyor, and is thus carried to the top of the sampling mill. The belt is 370 ft. long and travels with a speed of 300 ft. per minute. The total rise is 125 ft.

At the top of the incline is a no. 8 Blake-Denison automatic and continuous weighing and recording machine. Power for driving this elevator is taken from the main line shaft in the sampling mill.

Sampling Mill.—The ore from the inclined conveyor discharges into the feed hopper of a no. 3 Vezin sampler. This sampler will take a 5 per cent. cut, but is arranged so that a 10 per cent. cut can be taken if desired. The reject drops upon a 26-in. horizontal belt conveyor which runs over the battery storage bins.

The sample goes to a set of 26×15-in. style A rolls set for a ⅜-in. product, and discharges directly into a no. 2 Vezin sampler arranged like the no. 3 for a 5 per cent. sample, but capable of taking a 10 per cent. cut if desired. The rejection from this sampler goes to the bucket elevator and the sample goes to a six-ton sample storage bin on the floor below.

Up to this point the plant runs eight hours per day and will handle 600 tons of ore during that time.

Once a day the sample is drawn from the six-ton bin by a style H, Allis-Chalmers 16-in. wall type feeder into a no. 1 Vezin sampler, also arranged for a 5 per cent. cut. The reject goes to the bucket elevator and the samples to a small shaking feeder, which feeds it into a style A sample grinder, which makes a 50 per cent. cut. The reject goes to the bucket elevator and the sample drops directly into a style B sample grinder, also arranged for a 50 per cent. cut. The reject from this grinder is shoveled into the boot of the bucket elevator and the sample which goes into a sample bucket is again put through the style B grinder to be reduced again by one half. This gives the final sample in which one pound is equivalent to 64,000 lbs. of ore.

The bucket elevator is 51 ft. between centers, with 6×4-in. buckets spaced 12 ins. apart and runs with a belt speed of 300 ft. per minute. The boot is a standard steel boot, and the head has a geared drive, both of the Allis-Chalmers type. This elevator has a double discharge, delivering either directly into the battery ore bin

or upon the horizontal troughed belt conveyor on the top of the bin. This conveyor has a 26-in. six-ply rubber belt exactly like the inclined conveyor belt and it runs the entire length of the bin. It is equipped with a self-propelling, automatic distributor. Power for driving this conveyor is furnished by an independent 15-h.p. Allis-Chalmers motor running at 1,130 r.p.m., and placed at the far end of the bin.

Power for the sampling mill is furnished by a 75-h.p. Allis-Chalmers motor running at 680 r.p.m.

The main line shaft is $3\frac{15}{16}$ ins. in diameter and the upper and lower countershafts are $2\frac{7}{16}$ ins. and $2\frac{15}{16}$ ins. in diameter, respectively. Three- to six-ply rubber belts are used on all drives except the motor, which is a 15-in. endless double leather belt.

The sampling mill is a steel structure and adjoins the main mill building.

Main Mill Building.—The mill building, built on the side hill, is of the usual terraced construction and has four departments, all in one structure. The batteries occupy a section 50 ft. 6 ins. wide by 210 ft. long; the tube mills a section 62 ft. wide by 210 ft. long; the concentrator section is 60 ft. wide by 266 ft. long and the cyanide department is 222 ft. 6 ins. wide by 294 ft. long. The difference in elevation between the first wall and the last wall is 132 ft. 1 in. Below this last level is sufficient fall to carry the tailings to the tailings dam in the desert below.

The mill building is entirely of steel construction furnished and erected by the American Bridge Company, of New York. There is between 500 and 600 tons of structural steel in the building exclusive of the roofing and siding which is of asbestos-protected corrugated metal. On the first three terraces of the building, Fink trusses are used with spans of 50 ft. 6 ins., 62 ft. and 60 ft., respectively. In the other five sections, girder trusses 5 ft. deep are used. The foundations in the mill building alone, not including the crusher plant and sampling mill, contain about 7,000 yds. of concrete. About 30,000 yds. of rock were excavated for the foundations. All walls and piers for building columns are 24 ins. wide at the top and all have a standard batter of $1\frac{1}{2}$ ins. per foot.

Mortar Block and Battery Bins.—The mortar block, which is entirely of concrete, is 192 ft. 10 ins. long and 6 ft. wide at the top and has a cross sectional area of 96 ft. The anchor bolts are $1\frac{1}{2}$-in.

rods set in 2-in. pipe on an incline, with large apertures for the head, the object being to facilitate dropping the bolts sufficiently to remove a mortar in case one should break. The webs between these apertures are each reinforced with ¾-in. steel bars, 3 ft. long.

The ore bins behind the batteries are of structural steel and are an integral part of the mill building. They are 18 ft. 8 ins. wide, 20 ft. 6 ins. deep, and 187 ft. long. They are lined on the bottom, which is flat, with one layer of 4 × 8-in. timbers on edge and on the sides with one layer of 2 × 12-in. and one layer of 3 × 12-in. planks for half the height and two layers of 2 × 12-in. planks the remaining height. When full, these bins hold 4,000 tons of ore weighing not to exceed 125 lbs. per cubic foot.

The first ores mined in Goldfield were in an oxidized gangue, were free milling, and presented no special difficulty in extraction. The sulphide ores which appear a short distance below the surface, present considerable metallurgical difficulty, and these are the ores which the new mill has been designed to treat. F. L. Bosqui, as metallurgical engineer, and A. G. Kirby, as mill superintendent, have studied the problem in the Combination mill owned and operated by this same company, where detailed and comprehensive mill-run tests have been made for more than a year. From these results and the experience gained during the entire existence of the Combination mill running on Combination and Mohawk ores, the following process has been evolved.

Stamp Batteries.—The ore from the battery ore bins feeds through twenty 18 × 24-in. ore-bin gates into suspended Challenge feeders and thence into no. 120 G mortars. These mortars are of the modified Homestake type, with large opening for quick discharge, and weigh 10,500 lbs. each without liners; they are fitted with false bottoms made in halves. The screens are 16-mesh made of no. 21 steel wire. Each stamp weighs 1,050 lbs. and will make 108 drops per minute. The battery drive shaft is $3^{11}/_{16}$ ins. in diameter, and each cam shaft is 6½ ins. in diameter and 15 ft. 6 ins. long. The drive pulleys are of wood 84 ins. in diameter with a 17-in. face; like the cams they are keyed to the shaft by Blanton patent fasteners.

There are 100 stamps in all, arranged in batteries of 10, with five stamps per mortar as usual. Every 20 stamps are driven by a 50-h.p. Allis-Chalmers motor running 850 r.p.m., placed under the ore bin

and driving the drive shaft by means of a 13-in. endless double leather belt. The belts from the battery drive shaft to the cam shaft are 16-in. 8-ply rubber belts.

Each mortar, into which is fed six tons of water to each ton of ore, discharges upon a 5 × 16-ft. copper-plate table sloping 1⅞ ins. per foot. There are four plates per table, each 5 × 4 ft. ⅛ in. thick coated with one ounce of silver per square foot. In front of each plate is a cast-iron amalgam trap. The pulp from these plates goes to twenty 24-in. double-cone hydraulic classifiers, 1.2 gals. of water per minute being added at each of these classifiers. Of the pulp going to these cones, 35 per cent. will overflow and will run between 150 and 200 mesh. The balance or 65 per cent., which will run from 16 to 150 mesh, goes to six classifiers. This spigot product will contain 1.5 tons of water to one ton of dry slime, while the overflow will contain 15 tons of water to one ton of slime.

The classifiers, or more properly pulp thickeners, are of the improved type with the rocker motion on top and are arranged so that each feeds directly into a tube mill. The classifiers are sheet steel tanks 16 ft. long by 4 ft. 6 ins. wide and 18 to 30 ins. deep, set on a slope of 2 ins. per foot. Inside are a series of rakes made of angle iron set transversely, which move back and forth, pushing the pulp toward the top at each stroke and lifting clear of the pulp for the return motion, by means of a cam and rocker arm. The surplus water overflows at the lower edge of the tank. These classifiers will furnish to the tube mills a pulp which contains 46 per cent. moisture. This machine which is said to be furnishing a product, in several mills, carrying only 25 to 30 per cent. moisture, is the design of J. N. V. Dorr. The overflow from these classifiers goes to the clarifying tanks.

Tube Mills and Concentrators.—The product from the classifiers drops into a steel hopper and is there picked up by a spiral feed on the trunnion of the tube mill; the pebbles will also be fed by dropping them into this hopper to be picked up and fed automatically by the spiral feed. There are six tube mills of Allis-Chalmers manufacture, 5 ft. in diameter by 22 ft. long, placed three in each end of the building. Each group of three mills is driven by a separate 150-h.p. Allis-Chalmers motor running 570 r.p.m. It will require 80 h.p. to start a mill, but only 40 h.p. to keep it in motion. The motor belts are 25-in. endless double-leather belts.

The product from the six tube mills will go to six 48-in. double-cone, hydraulic classifiers. Here six gallons of water per minute are added and in addition sufficient overflow from the 24-in. cones to make the 48-in. cones classify properly. The spigot product from these, which will amount to 10 per cent. of the feed, is returned to the classifiers by four 10 × 54-in. Frenier sand pumps, running 187 r.p.m., to be returned and reground in the tube mills. The overflow from these 48-in. cones, which will run from 150 to 200 mesh and will contain five tons of water to one ton of dry slime, goes over fourteen 5 × 16-ft. secondary copper-plate tables sloping 2 ins. per foot. Each table has four 5 × 4-ft. plates coated with two ounces of silver per square foot. Seven of these tables are at each end of the mill and each seven discharge through a large amalgam trap made of 12-in. pipe.

All the overflow from the 48-in. cones, which has passed over the secondary plates, meets the overflow from the 24-in. cones and goes to thirty 8-ft. Callow tanks set next to the wall on the concentrator floor. These tanks are large sheet-steel, conical pulp thickeners and each tank will make 6 to 10 gals. of clear water per minute, which runs off the top and goes to the clarifying tanks below. This spigot product from each Callow goes to two concentrators. There are 70 concentrating tables in the mill, 10 of which will treat the middlings from the other 60. These 60 concentrators are arranged in three rows on the concentrator terrace and are driven by three 30-h.p. Allis-Chalmers motors running 850 r.p.m. The power is transmitted to the tables by line shafting equipped with Allis-Chalmers friction-clutch pulleys and friction-clutch cut-off couplings so that the various groups of tables are independent of each other. The table pulleys will run 300 r.p.m. The ten tables for treating the middlings are placed on a platform extending over the first row of settlers in the terrace below, and are driven by an independent 30-h.p. motor like the others.

Of the ore which comes to the mill, 3 to 5 per cent. goes out as concentrates; these concentrates will not be shipped to the smelter, but will be treated here by the Hutchinson process. This leaves 570 tons of dry slime per day to go to the settling tanks.

Cyanide Department.—There are five terraces in the cyanide department; the first two contain 16 settling tanks 29 ft. 6 ins. in diameter and 12 ft. high, with overflow rims and false conical bot-

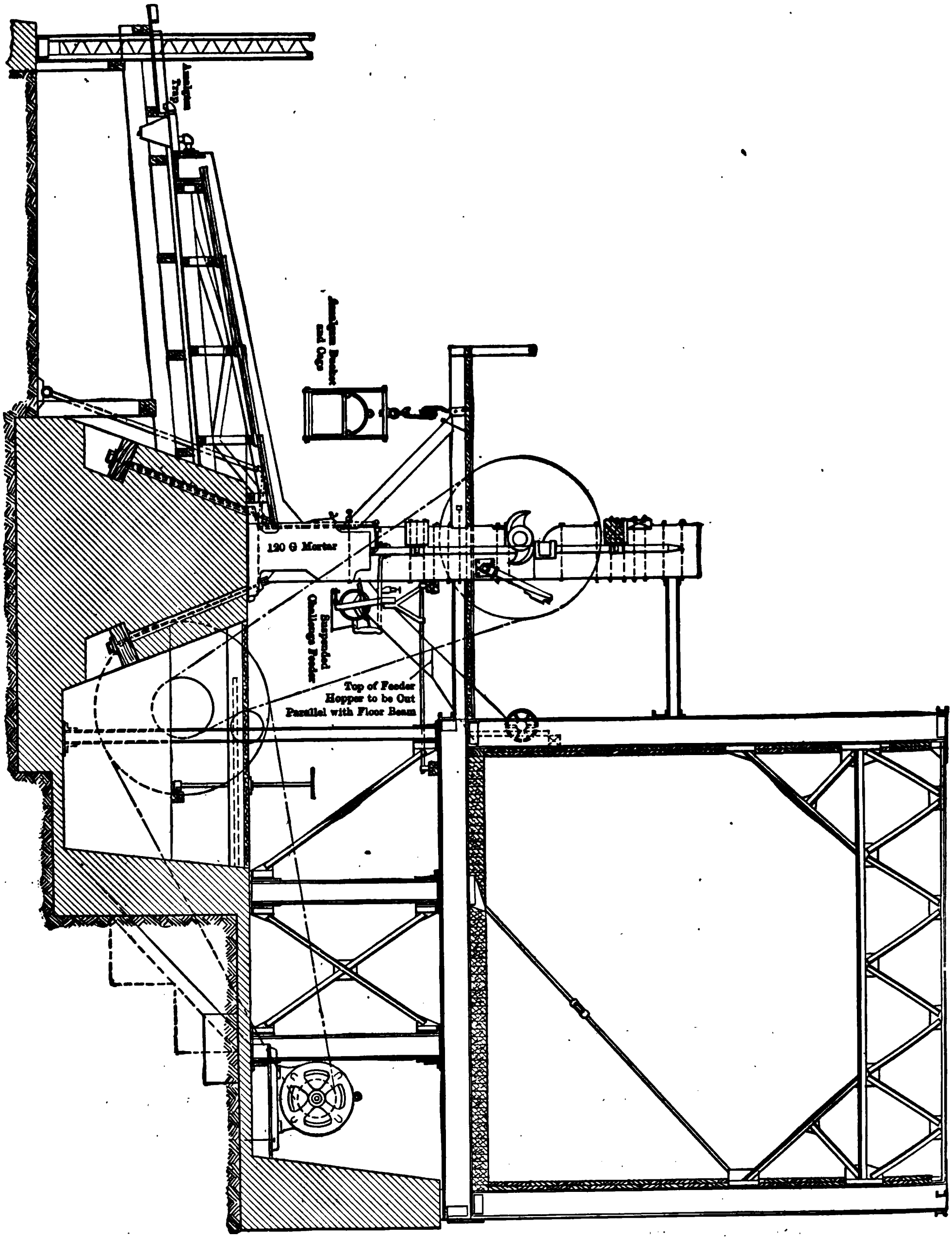


FIG. 65. ARRANGEMENT OF ORE BINS AND STAMP BATTERIES.

toms. These settlers, and all the other tanks in the plant except the agitators, are of redwood and are supported on concrete foundations. The slimes from the tables flow by gravity into the settlers, which are arranged in sets of four, one set being in process of filling all the time. The filling will require six hours and decanting and discharging will occupy the other 18 hours of the 24. These settlers will give a one to one pulp, one ton of water to one ton of dry slime, which goes partly by gravity and partly by pumps to the air agitator. The overflow from the settlers passes to two clarifying tanks, 34 ft. in diameter by 10 ft. high with overflow rims and false conical bottoms similar in every way to the settlers. These two tanks are set one 3 ft. below the other in order to get drop for the overflow, and the clear water flows by gravity to the water sump tank. From the sump the water is pumped by 10×12-in. triplex pumps direct-connected to Allis-Chalmers motors to the mill water supply tanks at the top of the hill. These three tanks have 6-in. discharge nozzles in the bottom, for drawing off the slime which will be returned to the $15' \times 45'$ tanks to be cyanided.

Air Agitators.—There are ten air agitators each 15 ft. in diameter by 45 ft. high built of sheet steel and supported on concrete foundations. The foundations are octagonal in plan to carry the circular bottom of the tank, with a 3-ft. square pier in the center to carry the small base plate. Cyanide is added to the pulp while in these tanks, and the solution is brought up to the required strength. The pulp in the tanks, which contains about 2½ tons of water to one ton of dry slime, is agitated by compressed air at 22-lbs. pressure for 20 hours.

The air-agitation tanks which are adopted from Mexican practice have never been used in this country prior to this installation. They consist of a steel shell and have a conical bottom. The lap joints are reinforced with angle iron and each tank is braced with nine triangular braces of angle iron from the center to the sides. In the center of each tank is an 18-in. tube extending from within 18 ins. of the bottom to about 23 ins. of the top. A 1½-in. pipe for compressed air extends inside the 18-in. tube down from the top of the tank to the bottom where it is open for the air to escape. The air from this pipe rushing up inside the 18-in. tube carries the solution up and over the top into the main tank, in which the level of the solution is kept continually a foot or more below the top of the

18-in. tube. This continuous air circulation provides both agitation and aeration. A one-inch pipe extends down the side of the 18-in. tube to the discharge at the bottom and a 2-in. pipe on the other side of the tube connects with an annular ring from which eight pipes radiate to the sloping sides of the conical bottom. These pipes are flushing pipes to dislodge any pulp which cake on the sides or bottom of the tank. Air at 50-lbs. pressure may also be used, and the piping is properly arranged for this purpose. When the agitation is completed after 20 hours, the pulp is discharged through a 5-in. pipe at the bottom into an 8-in. main running between the two rows of agitators and thence to 8-in. manganese-steel-lined, belt-driven, centrifugal pumps. Each tank has a 5-in. quick-opening iron gate valve close to the discharge connection. About 3½ h.p. per agitator is required for furnishing the compressed air. Each tank weighs 17¼ tons and when full of pulp about 200 tons.

Butters Gravity Vacuum Filter.—The pulp from the agitator tanks is pumped by two 8-in. centrifugal pumps to two tanks, which act as storage and supply tanks for the Butters boxes below. These tanks are 34 ft. inside diameter by 15 ft. high and are equipped with mechanical agitators operated by bevel gears from a common shaft driven by a 20-h.p. Allis-Chalmers motor.

There are two sets of Butters filter boxes each containing six sections of 28 leaves each, a total of 336 leaves. Each leaf is 5 × 10 feet. A 14 × 14-in. vacuum pump with direct-connected motor draws the gold solution through the filter frames and discharges it into the gold solution tank. A spare vacuum pump, a duplicate of the other, is provided for emergencies. These pumps are each driven by a 15-h.p. Allis-Chalmers motor.

When a cake ¾-in. thick has formed, containing per frame 360 lbs. of dry slime, the surplus pulp is drawn off into the surplus pulp tank. This tank is 36 ft. inside diameter by 10 ft. high and is also equipped with a mechanical agitator driven by a 10-h.p. Allis-Chalmers motor. Between cycles the pulp is pumped back into the pulp storage tanks by two 5-in. manganese-steel-lined, centrifugal pumps, which are set on opposite sides of a single 30-h.p. Allis-Chalmers motor connected by clutch, cut-off couplings; only one pump will be run at a time.

While the surplus pulp is being drawn from the boxes, the vacuum will be maintained at 10 in. in order to hold the cake on

the frame. The filter boxes are then filled with weak solution. The vacuum pump draws this weak solution through the cake and thus washes it, and then discharges the solution into the gold-solution tank. The remainder of the weak solution in the boxes drops by gravity into the surplus weak solution tank which is 36 ft. in diameter by 11 ft. deep and between cycles it is sent to the solution storage tank by 4-in. centrifugal pumps, each connected to a 20-h.p. Allis-Chalmers motor. Water from the water storage tank is now drawn through the cake, and this solution which is practically barren pumped into the gold solution tank. The surplus water in the boxes is drawn off by gravity into the surplus water tank 36 ft. in diameter by 11 ft. high and between cycles this is pumped by one of the 4-in. centrifugal pumps back into the water storage tank. An extra pump exactly like the other two is provided with by-passes and auxiliary piping to be used in case of accident.

Air or water pressure is now applied on the inside of the leaves in order to break off the cake. This drops into the steel hopper bottoms of the boxes and is discharged into the tailings flume directly underneath, which tunnels under the last terrace of the mill and discharges on the hillside to the tailings dam. These tailings will contain one ton of water to one ton of dry slime.

The leaves can be lifted from the boxes, to be washed in the acid wash boxes at the end of the filter boxes and are replaced ready for another charge. The leaves are handled by two crawls running on two 7-in. I-beam tracks overhead. Seven to eight charges per day will be put through the Butters filter. During filtering the pulp is circulated through the boxes by an 8-in. manganese-steel-lined centrifugal pump direct-connected to a 30-h.p. Allis-Chalmers motor.

Clarifying Presses.—The first solution from the acid solution tank is forced by a 4-in. centrifugal pump directly behind the presses, through three 36-in. square 60-frame Perrin clarifying presses which remove all slime. The strong solution then drops by gravity into two precipitation tanks. The weak solution from the Butters boxes to the gold-solution tank is forced by the same pump through these clarifying presses and is drawn back into the weak solution precipitation tank. These three tanks are 28 ft. in diameter by 8 ft. high.

A 12 × 14-in. duplex compressor in the south end of the terrace will furnish air to two air receivers having a capacity of 250 cu. ft.

for the agitators and the Butters boxes. The compressor is driven from a countershaft which also drives the two 8-in. centrifugal pumps which handle the pulp to and from the agitator tanks. Power for this is furnished by a 75-h.p. Allis-Chalmers motor.

The south end of this terrace next to the motor and compressor is divided into two rooms, one for a boiler.room for heating the mill in winter and the other for a cyanide office.

Refinery.—The clarified rich solution from the tanks are pumped by two 7 × 9-in. direct-gear motor-driven, triplex pumps to filter presses in the refinery, situated on the hill at the south end of the mill. As the solution is drawn from the solution precipitation tanks, zinc dust is fed automatically and continuously from two 25-in. zinc-dust cones between the tanks.

The filter presses, of which there are four, each containing thirty 48-in. triangular frames, are of a type devised and used by C. W. Merrill. When a clean-up from the presses is made, the zinc cake carrying the gold is put in pans and treated in a double muffle furnace where all the moisture is driven off and the material is partially roasted. The solution from the presses goes to two barren solution tanks 34 ft. in diameter by 12 ft. high, just outside the refinery building, one for weak and one for strong solutions, which are returned to the mill, the weak going to the Butters storage tank, and the strong being used for flushing out the settlers or passing directly to the air agitation tanks.

The roasted material from the muffles is ground in a 24 × 48-in. revolving barrel together with the necessary fluxes and the fine product resulting is treated in four Faber du Faure furnaces. These furnaces are equipped with oil burners, but can also use coke. The product from these furnaces is bullion and slag, the former ready for the mint and the latter to be sent to the smelters.

Amalgam from the primary and secondary plates is put through an amalgam press and as much quicksilver squeezed out as possible. The amalgam balls from this press are placed in semi-circular trays which are then transferred to a retort furnace where the mercury is retorted and recovered. The bullion from the retorts is refined in a no. 60 Steel-Harvey refining crucible, and the bullion product is ready for the mint. A 24 × 48-in. clean-up barrel is provided to grind the foul amalgam carrying sand, sulphides, etc., from the traps and mortars, and this ground product is then retorted and refined.

The retort and muffle furnaces are built together and will require for construction 9,000 red brick, 3,000 fire brick and 2,000 lbs. of fireclay. The red brick will be set in mortar. This compound furnace is equipped for burning crude oil, but is so arranged that it can also burn coke in case of need.

I-beam trolley tracks and crawls are provided in front of the Faber du Faure furnaces, and the muffle furnaces for handling crucibles, pans, and heavy material. A reinforced concrete vault is provided in the refinery for storing bullion and other valuable material. A 10-h.p. Allis-Chalmers motor will furnish all the power required. The refinery will have two stacks, one for the Faber du Faure furnaces 24 ins. in diameter and 60 ft. high and one for the retort and muffle furnace 20 ins. in diameter and 30 ft. high.

Power.—All the motors in the plant are three-phase, 440-volt, 60-cycle machines, and receive current from the transformer house on the hill behind the mill building where three Allis-Chalmers transformers step down a 6,600-volt current derived from the long-distance line of the California & Nevada Power Company at Bishop, Cal., 150 miles away, which is equipped with Allis-Chalmers Water Wheel Generators. There will be 1,305 h.p. of Allis-Chalmers motors in the plant as follows:

	Number.	Horsepower.
Crusher plant	1	150
Sampling mill	1	75
Horizontal belt conveyor	1	15
Stamp batteries	5	50
Tube mills	2	150
Concentrators	4	30
Compressor and belted pumps	1	75
Pulp agitators	1	10
	1	20
Direct-connected Pumps.		
Centrifugal pump	1	30
Centrifugal pump	3	20
Centrifugal pump	1	20
Vacuum pump	2	15
Triplex pump	2	15
Triplex pump	2	40
Refinery	1	10
Shop	1	10
Tramway	1	20
Total		1,305

Water.—The water supply is obtained from the Goldfield Water Company's mains and is a pure spring water brought from Lida 38 miles to the south. From the water company's mains to the reservoir a 5-in. wire-bound redwood pipe is used. The reservoir is situated on the westerly side of Columbia Mountain about 1/4 mile from the mill site, at a slightly greater elevation, and consists of eight 30 × 20-ft. redwood tanks having a total capacity of 800,000 gals. The water from the reservoir flows to a clear-water tank of the same dimensions on the mill-site hill, and thence to a mill-water tank of the same dimensions just below the former tank, and just above the battery ore bin. From this tank the water flows to the main in the mill.

An incline tramway, 30-in. gauge, operated by a 20-h.p. motor will reach from the lowest level of the mill to the top of the hill for handling supplies and material. The motor will be placed in a small addition to the shop building just south of the refinery. A 10-h.p. motor will run the shop, which is a small one, and intended only for small repairs, as the company has an extensive machine-shop equipment at the mines.

CHAPTER VII.

THE LAYOUT, DESIGN AND CONSTRUCTION OF SILVER REFINERIES.

THE SILVER REFINERY OF THE NEW ADDITION TO THE RARITAN COPPER WORKS.

Silver Refinery.—The process of smelting and refining is divided into three stages, each of which is carried out in a separate room. Fig. 66 shows a ground plan of the refinery.

On account of the high monetary value of the material handled, precautions have to be taken to guard against losses other than metallurgical. In Fig. 70 is shown the arrangement of lockers, etc., for the employees, which may be of sufficient interest to describe them in greater detail.

Special provision was made for the comfort and convenience of the working force, white porcelain-lined wash stands, hot and cold water and shower baths being provided, together with two lockers for each employee, one for his street clothes and the other for his working apparel, the idea being that if comfortable, scrupulously clean and sanitary surroundings were provided, a standard would be established, whereby the force could be held and maintained at that degree of cleanliness and carefulness which is so essential in the successful operation of a refinery treating electrolytic slimes.

All employees enter the no. 1 locker room by the door nearest the entrance, remove their outside street clothes, place them in their respective lockers and pass through the door leading to the no. 2 locker room. This door is opened from either side only by a key which is in the possession of the special watchman. After donning their working clothes, the men go directly to their respective departments without passing through either of the others. On leaving work the reverse takes place, the laborers first washing up (the waste waters from the sink going to suitable settling tanks) before passing through the door to the no. 1 locker room. All the windows of the refinery are protected by small diamond mesh screens.

The buildings were constructed of brick with monitors running the length of the roof for ventilating purposes, with the exception

of the melting room in the parting plant, where two 48-in. Burt ventilators were installed. The roof trusses in the slime room are of timber, while those in the furnace building and parting plant are of steel.

A 5-ply asphalt and slag roofing laid over book tile was used in place of planking in the parting plant to prevent the possibility of a fire from spontaneous combustion, due to the action of nitric acid fumes on wood. All flashing throughout was of 16-oz. copper, and

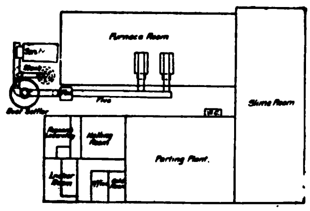


FIG. 66. PLAN OF SILVER REFINERY.

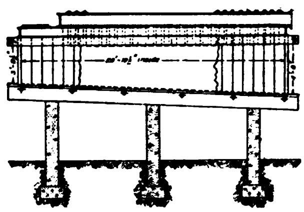


FIG. 67. SECTION THROUGH SCRUBBER.

exposed woodwork both inside and outside of the building was covered with three coats of Toch Bros. iron oxide paint.

The following gives an outline of the process for smelting slimes:

Stage.	Department.	Treatment.
1st	Slime room	Copper extracted. Slimes pressed and washed.
2d	Furnace room	Slimes melted and blown up to bullion.
3d	Parting plant	Gold and silver separated electrolytically.

Slime Room.—The general scheme for handling the slimes here is by the gravity system. After being screened first through a copper plate perforated with 1-in. holes, then through a slotted copper screen equivalent to 40 mesh to remove as much of the copper as can be removed by screening, the slimes are pumped from the tank house basement to receiving tanks in the top of the slime room by a centrifugal pump of the same design as that used for circulating electrolyte in the tank house.

All overflow water, together with the water used for washing slimes in the filter press, is returned to the tank house, where it is added to the electrolyte to make up losses by evaporation, etc., the water first passing through a system of settling tanks arranged on the gravity plan to allow the lighter particles to settle. The slimes are transferred from the receiving tanks to the agitators through a pipe and plug seat located in the bottom of the receiving tank.

In the agitators, which are large, circular, lead-lined tanks, the

slimes are boiled with sulphuric acid, sodium nitrate being added to hasten the process. Paddles constructed of lead containing 10 to 12 per cent. antimony and turned by machinery, prevent the slimes from settling to the bottom of the tanks in a solid mass. Practically no difficulty whatever is experienced with the machinery in this room due to acid fumes, and the use of machinery tends towards reducing labor costs.

After the copper in the slimes is reduced to a small amount they are transferred to an "egg"—a lead-lined cast-iron vessel, from which, by means of compressed air, they are forced into the Bushnell filter press, where the slimes are pressed and washed free from copper sulphate.

The plates and rings of this press are made of antimonial lead heavy enough to withstand the pressure used. Sulphuric acid solutions gradually attack plates made of copper or copper alloys.

The pressed slimes are unloaded directly into trucks which are run in under the press. After sampling and weighing they are ready to be transferred to the furnace department. It will be noted that this is the first point where a determination is made of the actual amounts of silver and gold recovered from the copper bullion.

The amount of copper remaining in the screened slimes varies from 8 to 18 per cent.; in certain cases where anodes are cast directly from converter copper, it will assay as high as 50 to 53 per cent. The leaching of this copper from slimes is made necessary because of the fact that when smelted in furnaces copper and silver form a compound assaying very high in silver, which is "slagged off." This not only diminishes the immediate output, but also increases the amount of silver tied up in process, thereby extending the time necessary to ship as fine product.

The method of extracting copper by boiling with acid and nitre is a slow reaction, despite the fact that copper exists in the slimes in a minute form. The process leaves much to be desired. Ten to 15 day's time is required to ship slimes as fine silver and gold, calculating from the date they are received from the tank house.

Furnace Room.—In this department the slimes are smelted in furnaces and refined by means of air blown on the molten surface to about 98 to 99 per cent. gold plus silver.

Fig. 68 shows views of the furnace used to smelt slimes. The hearth is made of chrome brick, and is 5 ft. 6 in. wide by 8 ft. long. Oil is used for fuel, burners furnished by the Rockwell Engineering

Co. being used. In the refining process, tellurium is among the last of the impurities to leave silver bullion, its presence requiring a prolonged operation with an accompanying loss of silver.

The refined bullion is dipped from the furnaces and cast by hand into thin plates, which form the anodes used in the electrolytic parting plant.

No lead is used in refining slimes, and the slags, after sampling and weighing, are sent to the copper furnaces. This tends, of course, toward a gradual increase of impurities in the material handled.

For recovering values mechanically carried into the flues, or volatized during the smelting process, an arrangement of flues shown in Fig. 66 was constructed. The gases are exhausted from the fur-

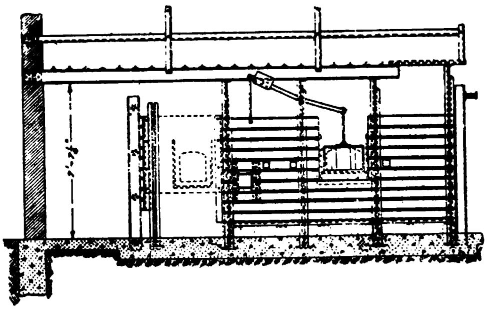


FIG. 68. SLIME FURNACE.

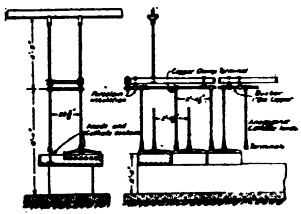


FIG. 69. SECTIONS OF COMPLETE CELLS.

naces by a fan which forces them first through a large settler, to allow the greater part of the dust to settle, and then through a water scrubber, before escaping to the air. In Fig. 67 is shown a view of this scrubber.

Slimes as charged into the furnaces contain from 40 to 50 per cent. silver, together with considerable gold, depending upon the copper bullion refined.

There is need of intelligent, earnest, systematic research work in the method of refining slimes, particularly on slime room and furnace methods, and the establishment of a research laboratory by the consulting engineers, Messrs. Fischer and Nevill, was in line with the advanced policy pursued by them throughout the construction of the plant.

Parting Plant.—After investigating different processes in use for the electrolytic separation of gold from silver, the method de-

vised by Mr. William Thum, which is a modification of the method described in full in his patent specification, was the one adopted as best suited for the work in hand.

The chief difference between this method and Balbach's (U. S. Patent no. 588,524) is, that in the former the electrodes are set at a slight incline from the horizontal, thus permitting solutions of heavier specific gravity which are formed directly under the anode case to mix more readily with the rest of the electrolyte. In the Thum process a flexible arrangement of cells can be made, whereby the current used may be shunted from the tank house electrolytic circuits. This provides cheap power and does away with the necessity of installing separate generators.

The cells are constructed of white acid-proof chemical stoneware, the bottoms of which are lined with flat slabs of carbon carefully fitted so as to make tight joints. These form the cathodes. Fig. 71 shows details of the anode case and Fig. 69 cross and longitudinal

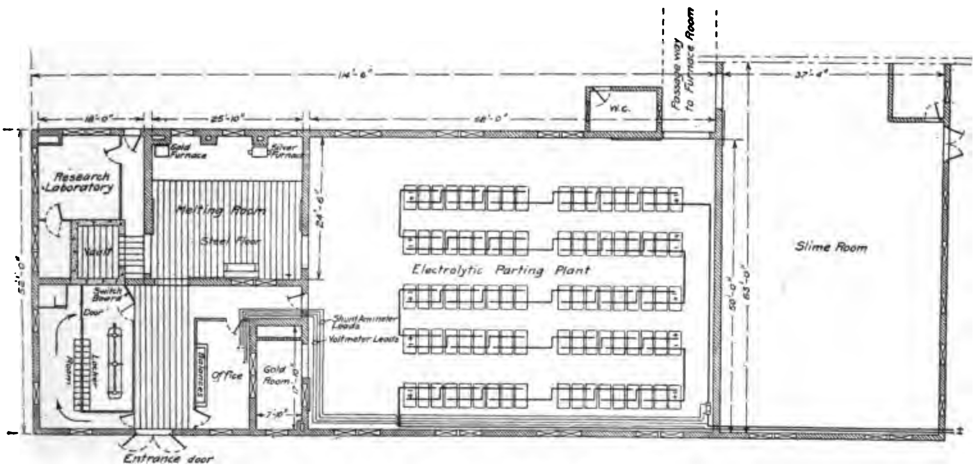


FIG. 70. FLOOR PLAN OF PARTING PLANT AND LOCKER ROOM.

sections of complete cells. Three cells are in parallel, with 3.5 sq. ft. of anode surface per cell. A current density of 40 amperes per sq. ft. is used.

The cathode contact pieces are cast of fine silver and last indefinitely. Anode contacts are cast of bullion. These contacts are cast in specially constructed molds, a threaded end being cast directly from the hot metal. In Fig. 72 is shown a detail of the method of connecting silver contact pieces with the busbar which runs overhead.

The general arrangement of plant is such that one aisle is used exclusively for the removal of deposited silver and the adjoining one for the removal of gold mud which remains on the canvas tray. Deposited silver is scraped from the bottom of the cells, removed in trucks and washed free from the copper silver nitrate electrolyte. A hard-rubber pump furnished by the American Hard Rubber Co. handles the wash water and raises it to a storage tank. After washing and drying, the silver is melted down in a tilting crucible furnace and cast into bars weighing approximately 1000 troy ounces, assaying 999 parts per 1,000 fine silver. Fig. 73 shows a view of the furnace used for melting fine silver. The gold mud is removed

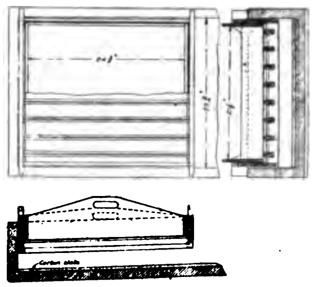


FIG. 71. DETAILS OF ANODE CASE.

in trucks, boiled first in nitric, and finally in sulphuric acid. It is melted in an oil-fired crucible furnace made by the Rockwell Engineering Co.

Sulphate Building.—Waste solutions from both tank houses are worked up in this department. The free acid is neutralized by allowing it to flow over shot copper, the copper being exposed alternately to solution and air. After concentration, the solution is run into small tanks where the bluestone crystallizes on lead strips.

Foundry Machine Shop and Smithy.—A word should be said in regard to these departments, which play an important part in the economics of copper refining; the necessity of making repairs quickly, and of keeping the mechanical equipment in perfect working condition being of prime importance.

The foundry building is a frame structure 49 ft. × 56 ft., and is equipped with a 6-ton crane. An elevated trestle, which is used for conveying pig iron, coke, etc., connects the railroad track directly with the charging floor of the cupola.

All the iron molds used for casting copper anodes are poured here, as well as the necessary parts needed for making repairs.

The smithy is a building of brick construction 20 ft. × 67 ft., a large monitor providing ample ventilation. Besides the customary forges, it is equipped with a steam hammer, punch and shears. The machine shop is a combination brick and frame structure 49 ft. ×

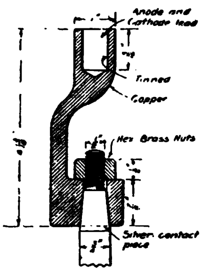


FIG. 72. CONTACT CONNECTION.

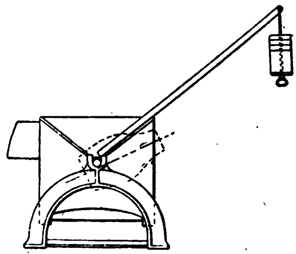


FIG. 73. FINE SILVER MELTING FURNACE.

80 ft. It is painted white inside which, together with the large number of windows, gives a well-lighted interior. The building is divided into three bays, while a crane in the middle bay provides facilities for handling heavy work. The equipment includes a milling machine, 5-ft. radial drill, grinder, 30-in. planer and one 14-in., two 18-in. and one 28-in. lathes.

CHAPTER VIII.

THE LAYOUT, DESIGN AND CONSTRUCTION OF SAMPLING PLANTS.

To separate an average portion from an entire lot or mass of material is technically known as "sampling." At metallurgical works sampling is performed for the purpose of securing a convenient amount of material to handle which will represent the average value of the mass from which it is taken and which, when analyzed, will show what the constituents of the material in hand are and their proportions to the whole.

Ores are sampled to determine their value and to ascertain of what materials their mineral and gangue portions are composed, so that suitable treatments for them may be decided upon.

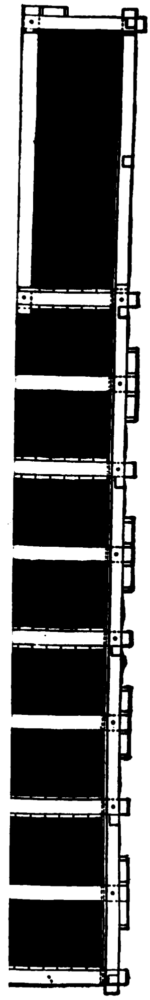
Sampling essentially consists of crushing and dividing. It is performed either by hand or by machinery. When done by hand the materials are first crushed to a suitable size for handling, mixed, and worked into a uniform mass. The mass is then divided into several parts and one of these parts separated from the remainder. This part is again mixed, divided, and a part separated as before; this same operation being continued until a final sample of the desired size is secured. Usually, however, the material is recrushed once or more times between the dividing operations, the extent of this crushing depending upon the size desired for the final sample.

When sampling is performed by machinery, the process is essentially the same, excepting that the material is usually reduced between each of the dividing processes.

All up-to-date smelters, whether they treat only their own ores or do custom work, have sampling plants, as only by this means can they keep a check upon the results they are securing. Other metallurgical plants, such as concentration plants, cyanide plants, and lixiviation plants, use sampling plants, to determine primarily the value of the ores they are treating and to keep a check upon the work of the plant.

A sectional elevation and plan of a large Automatic Sampling Mill ordinarily rated at a capacity of 35 tons per hour is shown in


ORE BIN



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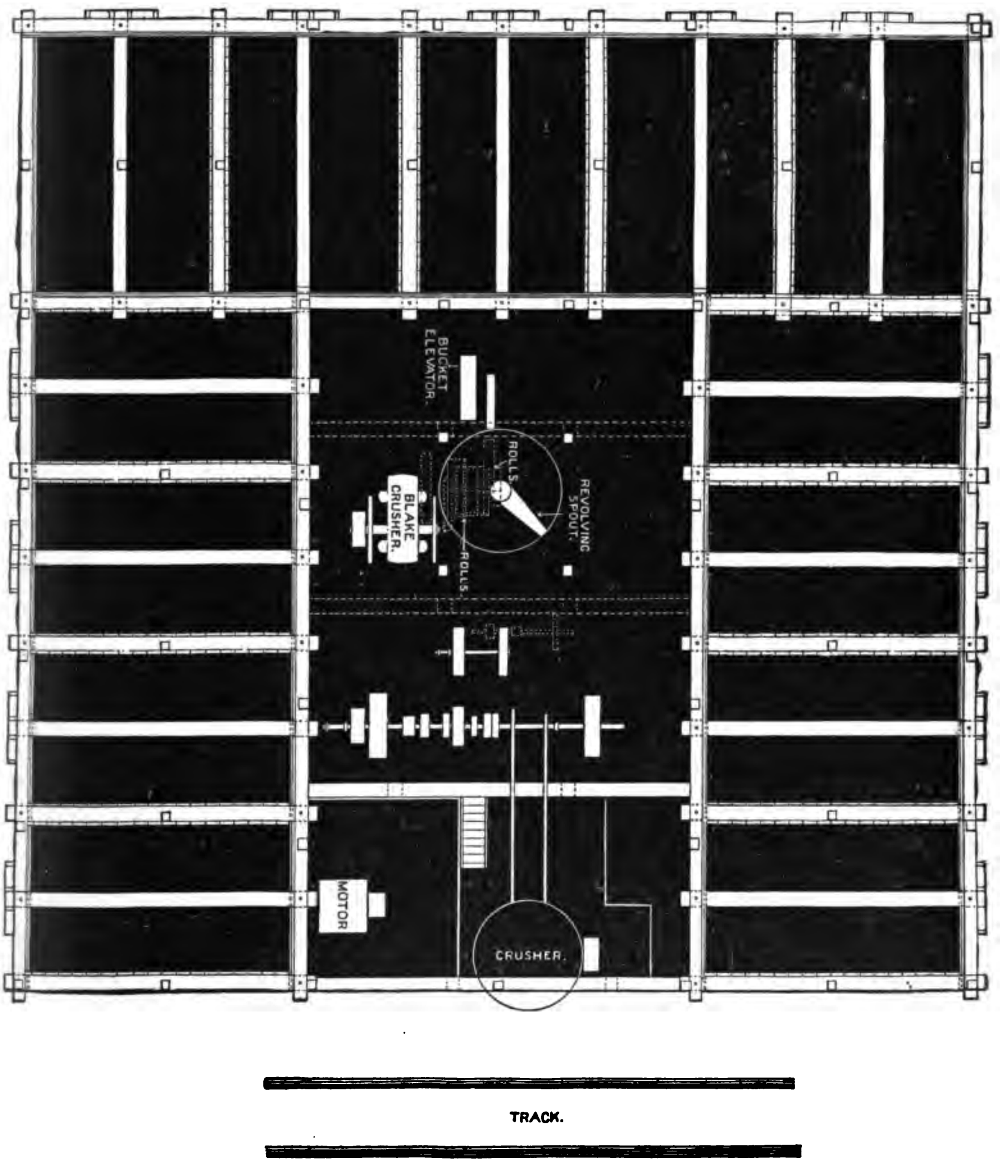


FIG. 75. PLAN OF LARGE AUTOMATIC SAMPLING PLANT.

Figs. 74 and 75. The course of the ore through this mill is as follows:

On being received it is fed into a no. 5 Gates rock and ore breaker, which reduces it about to a 3-inch size. It falls to a no. 6 Gates elevator, which raises it to the 60-inch Snyder automatic sampler at the top of the mill. This sampler takes a 15 per cent. cut, the rejections dropping into a distributing hopper directly below the sampler. The sample itself falls to a 9 × 15 in. Blake crusher. This crusher reduces it to about a 1½ in. size and from there it falls to a 42 in. Snyder automatic sampler. This sampler takes a 20 per cent. cut, the rejections falling to a 10 in. bucket elevator and the sample to a pair of 24 × 14 in. rolls. These rolls reduce the sample to about three quarters of an inch in size. From these it falls to a 27 in. Snyder automatic sampler. This sampler also makes a 20 per cent. cut, the rejections falling as before to the 10 in. bucket elevator, and the sample falling to a pair of 18 × 10 in. rolls. These rolls reduce the sample to about a ¼ in. size. From the rolls the sample falls to a quartering floor, where it is quartered down to the desired size and finally reduced in a sample grinder.

The 10-in. bucket elevator raises the rejections from the 42-in. and 27-in. samplers to the top of mill and discharges them into the distributing spout under a 60-in. sampler. This distributing spout is arranged to revolve and direct the ore into any of the various bins of the mills as desired.

This mill gives a 6-pound sample on the quartering floor for each 1,000 lbs. passed through the mill.

An automatic sampling plant, ordinarily rated at a capacity of about 5 tons per hour, is shown in section and plan in Figs. 76 and 77. The course of the ore through this plant is as follows:

The ore is first fed into a 7 × 10 in. Blake crusher, which reduces it to about 2 ins. in size. From there it passes to an 8-in. bucket elevator, which raises it to a 42-in. Snyder automatic sampler in the upper part of the mill. This sampler makes a 20 per cent. cut, the rejections passing to a bin in the front of the plant and the sample falling to a pair of 24 × 8 in. rolls. These rolls reduce the sample to about one inch in size. From them it passes to a 6-in. bucket elevator. The elevator raises it again to the top of the mill to a 27-in. Snyder automatic sampler. This sampler makes a 20 per cent. cut, the rejections passing to a bin in the front of the

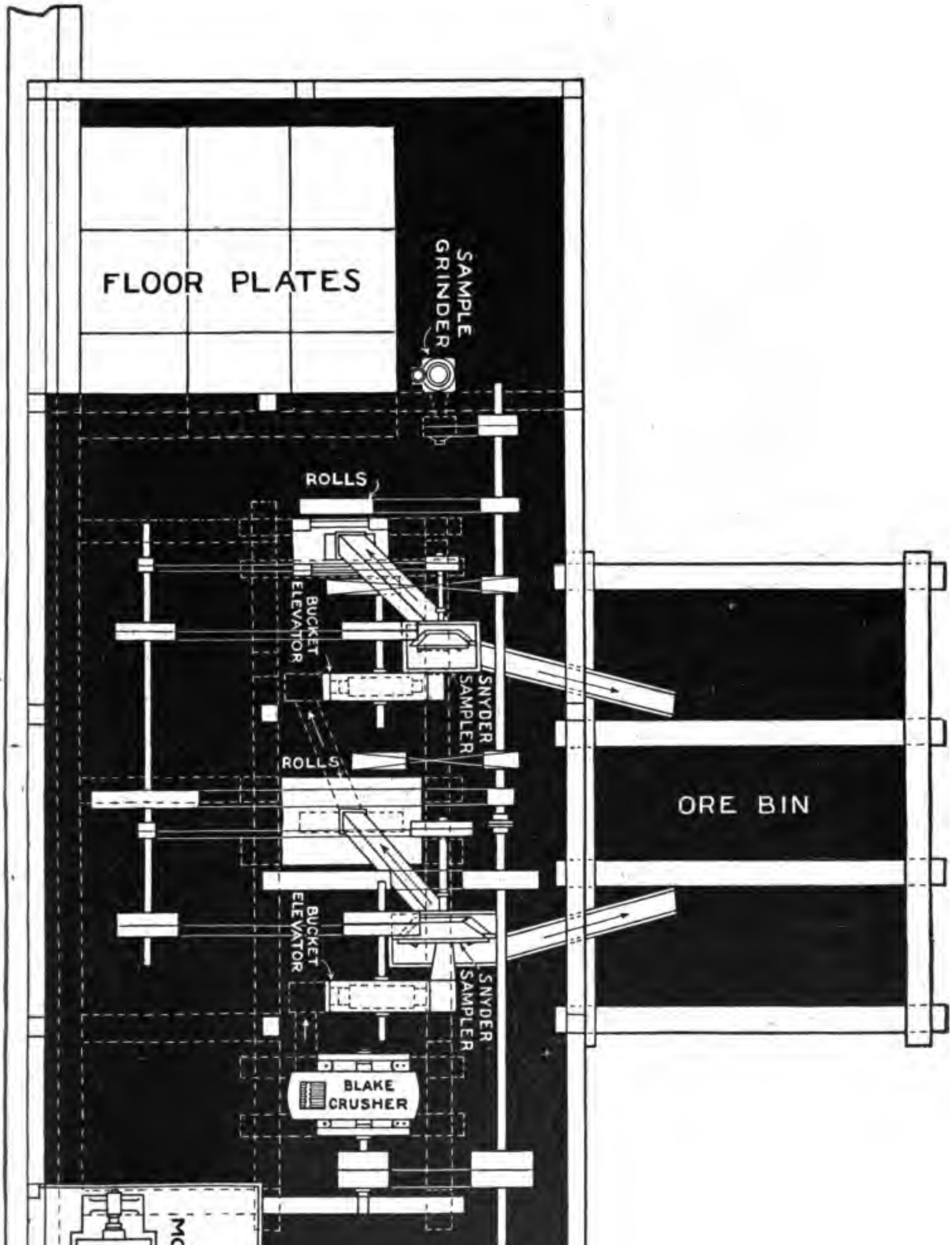


FIG. 77. PLAN OF SMALL AUTOMATIC SAMPLING PLANT.

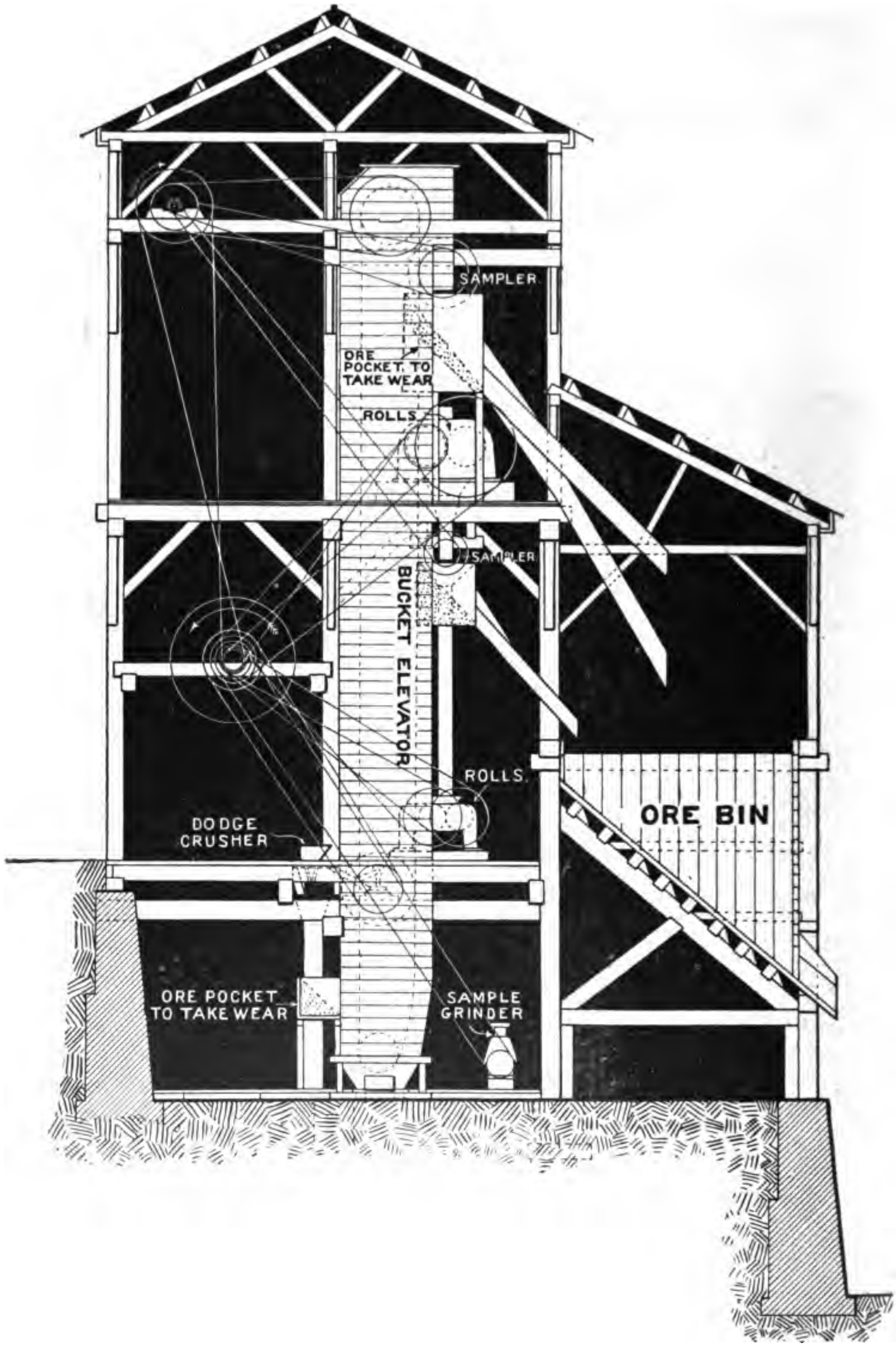


FIG. 78. AUTOMATIC SAMPLING PLANT. (SIDE ELEVATION.)

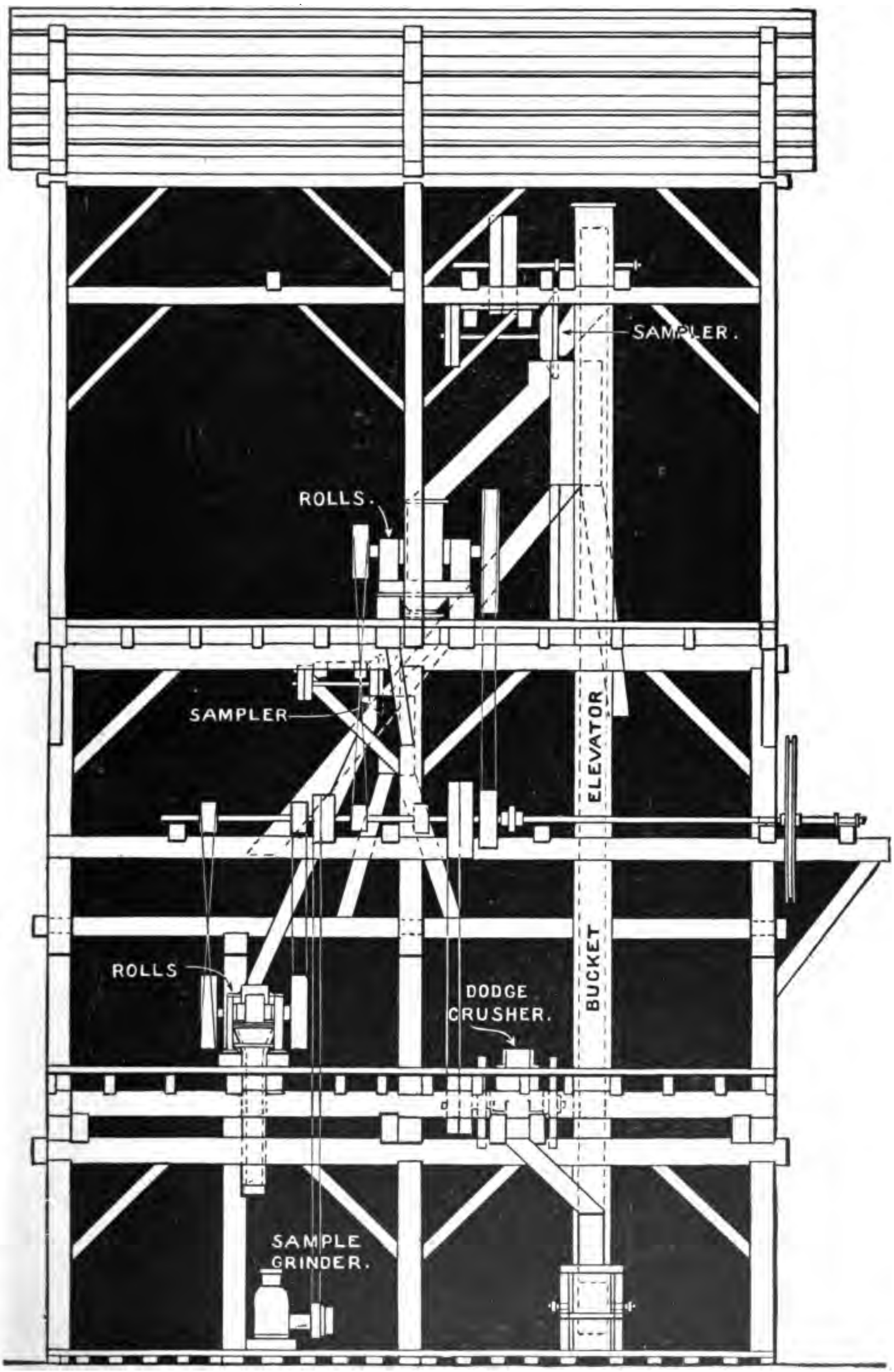


FIG. 79. AUTOMATIC SAMPLING PLANT. (FRONT ELEVATION.)

plant and the sample falling into a pair of 12 × 12 in. rolls. These rolls reduce the sample to about 1/4 in. in size and it falls to a 12-ft. square steel-covered quartering floor below. There the sample is quartered down to the desired size and the final sample reduced in a Style "B" sample grinder.

This mill is entirely automatic in its operation. It gives a 40-lb. sample on the floor plates for each 1,000 lbs. of ore passed through it.

An elevation and plan of an automatic sampling mill, ordinarily rated at a capacity of 7 to 8 tons per hour, is shown in Figs. 78 and 79. The course of the ore through this plant is as follows:

The ore is first fed into an 11 × 15 in. Dodge crusher, which reduces it to about a 2-in. size. From there it falls to a 10-in. bucket elevator, which raises it to a 42-in. Snyder automatic sampler at the top of the mill. This sampler makes a 20 per cent. cut, the rejections passing to a bin in the front of the plant and the sample itself to a pair of 24 × 14 in. rolls. These rolls reduce it to about 1 in. in size. From these it passes to a 27-in. Snyder automatic sampler. This makes a 20 per cent. cut, the rejections passing to a bin in front of the plant as before and the sample to a pair of 16 × 10 in. rolls. These rolls reduce it to about one-quarter inch in size and it falls from them to a 9-ft. square steel quartering floor on the lower level of the mill. Here the sample is quartered down to the desired size and the final sample reduced in a style "B" sample grinder.

This mill gives a sample of 40 lbs. on the quartering floor for each 1,000 lbs. passed through. Its operation is essentially automatic.

CHAPTER IX.

LAYOUT, DESIGN AND CONSTRUCTION OF STAMP MILLS.

The arrangement of a stamp mill is usually as follows: The ore is brought from the mine to the mill on cars with a capacity of ¾ to 1 ton, dumped onto an inclined screen, called a "grizzley," made of steel bars placed from ¾ in. to 1½ in. apart. The finer particles fall through this grizzley into a bin, while the coarse material is fed to a crusher which discharges its product to the same bin. This bin is provided at its lower side with ore gates to regulate the flow of ore to automatic feeders, one for each mortar, which discharge the crushed ore automatically to the batteries. Each battery consists of a cast-iron mortar usually with five stamps (though sometimes 1, 2 or 3 only are used).

The operation of a stamp mill may be likened to a hammer and anvil, in which the stamp shoe represents the hammer and the die the anvil, the ore being crushed between the two. The mortar is a heavy cast-iron box provided with an opening in the back for receiving the ore and fitted with a screen at the front, through which the crushed ore is discharged. On the inside bottom of the mortar are placed dies, which can be renewed when worn out.
The shoes are usually made of steel, and are fastened to the boss or stamp head with wooden wedges, which in turn is secured to the stamp stem. These together with the tappet, which is keyed to the stem, constitute the stamp proper and determine its weight, which varies from 150 lbs. to 1,200 lbs. The primary object of the tappet is to serve as a collar for lifting the stamp by the aid of revolving cams mounted upon a cam shaft. Cams are usually double-ended, so that the tappet with its stem, head and shoe is raised and allowed to drop on the ore twice in each revolution of the cam shaft.

Water is fed to the ore in the mortar through the feed box, or preferably through the top of the mortar.

A punched steel, or woven wire screen mounted upon a wooden frame is fitted to the discharge side of mortar and held in place with steel keys. The size of openings in the screen determine the maximum size of particles that may issue from the mortar. The stamps dropping into the pulp set up wave-like motions causing it to

splash against the screen, forcing particles of ore small enough to pass through its meshes, to issue with the water. The amount of battery water required varies with the character of the ore and the capacity of the stamps.

When the pulp issues from the mortar it passes over silver-plated

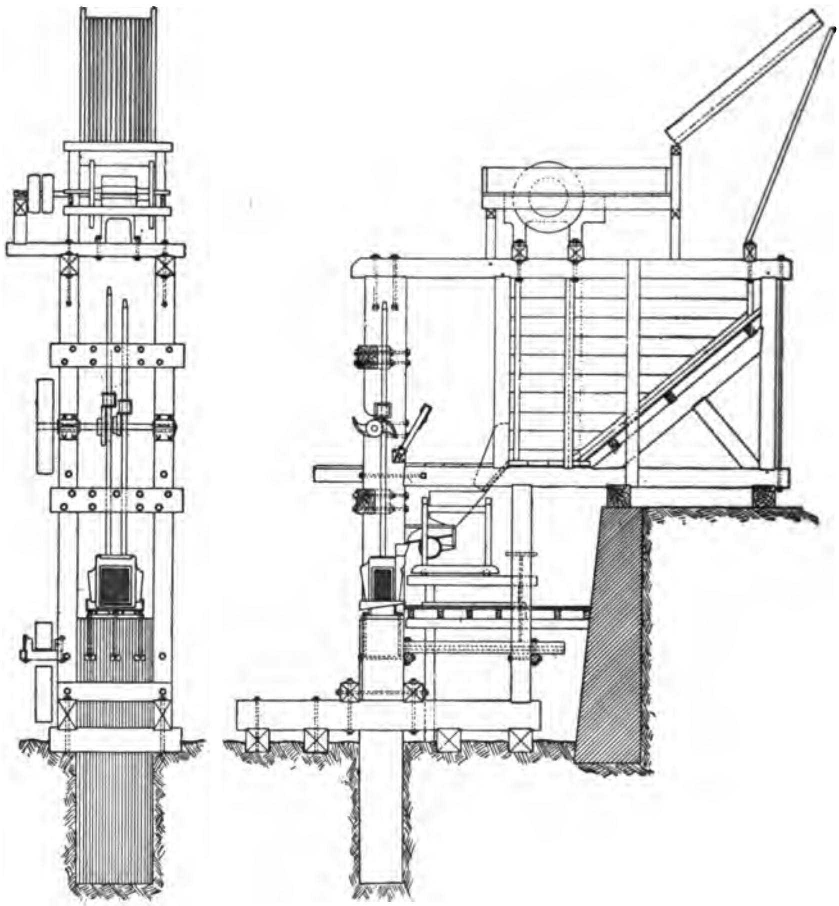


FIG. 80. TWO-STAMP MILL WITH SCREEN OPENINGS ON ALL FOUR SIDES OF MORTAR.

apron coppers, or concentrators, or other devices, for further treatment.

The two-stamp mortar, which we illustrate in Fig. 80, has been designed to meet a growing want among miners and millman for a stamp battery that will crush the greatest amount of ore with the least expenditure for plant and minimum weight.

This mortar has screen openings on all four sides, but has no copper plates inside of the mortar, the object being to get the pulp out of the mortar as rapidly as possible, and to accomplish this purpose the top of the die is kept well up to the screen opening, and the stamps are run 100 drops a minute, having a weight of 950 lbs. each. Chuck blocks, steel lined, are used to equalize the depth of the discharge as the dies wear down.

For Gold Milling.—In order to bring the ore in contact with copper plates and amalgamate the gold as much as possible without

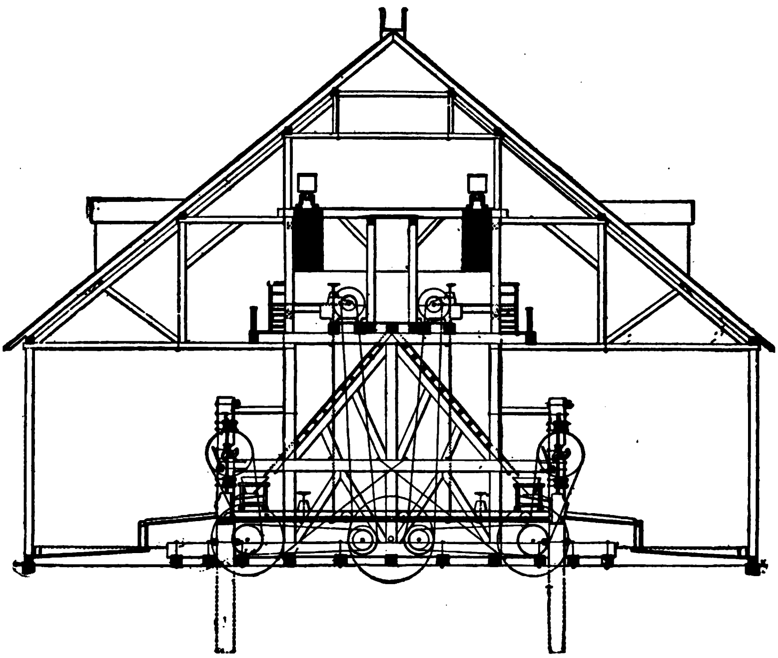


FIG. 81. GOLD MILL.

having excessively long tables, the sluices and lips of the mortar on all four sides are lined with copper plates electro-plated, and in this manner a greater surface for plate amalgamation is obtained than in the old method of inside plates and chuck block plates. The base of this mortar is very heavy. In order to reduce the weight, the top of the mortar above the screen openings has been cut down, so that instead of, as in the ordinary mortar, having the stamp stems pass through the wooden housing at the top of the mortar, the stamp head passes through. This housing is held in place by means of wrought iron keys in such a manner that it does not bear against

the stamp head, and the wood is of such depth that it is not possible for any splash to pass up between the wooden housing and the stamp head. The feed spout is provided with a sheet iron hopper, and on the inside has a steel lining plate to take the wear where the ore passes in.

Referring to Fig. 80, showing the two-stamp battery and ore bin:

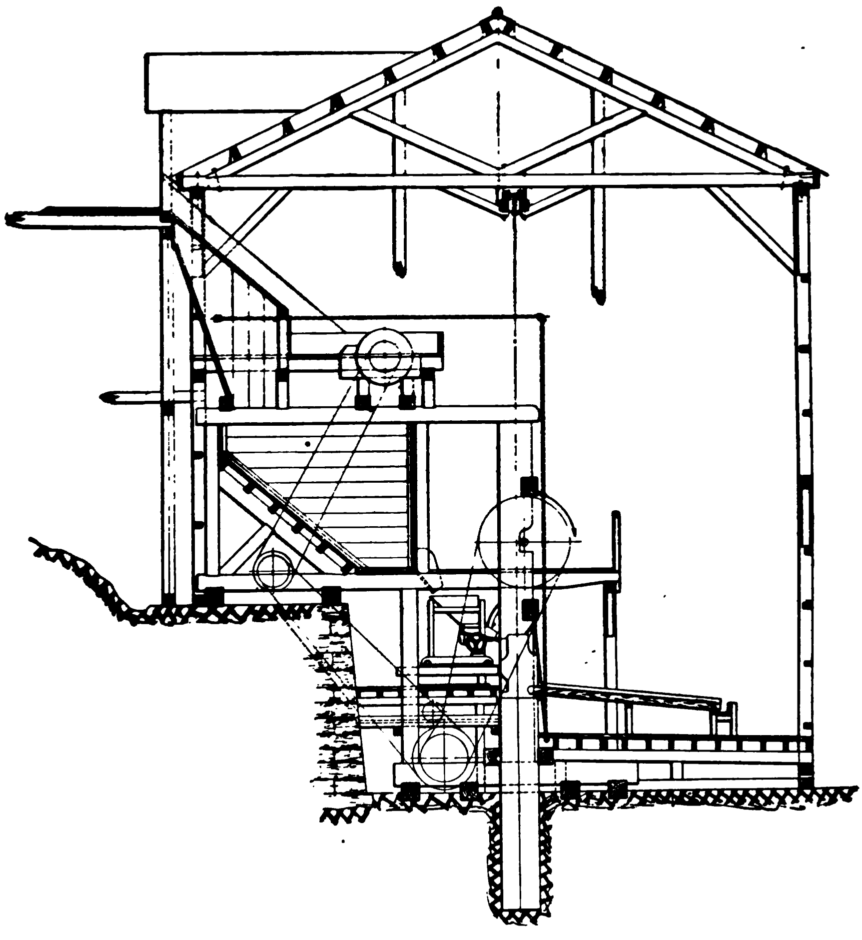


FIG. 81a. GOLD MILL.

In order to facilitate the cleaning of the copper plates in the side sluices of the mortar, the distance between the battery posts is made 4 ft. 6 ins. The posts themselves are the regulation width, 12 in. making a battery frame with a width practically the same as for a five-stamp battery.

These mortars are arranged in single batteries of two stamps as shown, or with four stamps on one cam shaft, in arrangement corresponding to that of ten-stamp battery, with the exception that we have four stamps instead of ten. Thus, while keeping practically the same output, it requires less power, and as parts of the battery are somewhat smaller on account of the less power required, the weight is considerably less.

Gold Mill (Fig. 81).—This shows the general arrangement of a simple gold mill. The ore is dumped over an inclined grizzley to the rock crusher floor. It is then passed through the rock crusher into ore bins, from which it is drawn through inclined chutes controlled by ore gates, as fast as required, into automatic feeders which supply the stamps automatically. Inside of the mortar are placed one or more copper plates, after being well scoured and covered with quicksilver. The table in front of each mortar is covered with a copper plate, size being same width as mortar, and 6, 8, 10 or 12 ft. long (the usual length is 8 ft.). These copper table plates are first well scoured and cleaned and amalgamated with quicksilver. Small quantities of quicksilver are occasionally dropped into the mortar while the stamps are running. Free gold is caught on the inside copper plates and outside copper tables by means of the quicksilver forming gold amalgam, which at intervals is scraped off and retorted (vaporizing the quicksilver which is condensed in water), the gold thus gained melted and run into moulds and the quicksilver saved for use again.

The above described plate represents a cross-section through the mill, showing an end view only, and serves to illustrate this same view in mills of any number of stamps.

Fine Concentration Works Improved Twenty-Stamp Mill For Gold Ores.

(Arranged With Gyratory Breakers, Frue Vanners and Hydrometric Sizers.)

Fig. 82 illustrates a 20-stamp gold mill with concentrators, the ore car dumping over an inclined grizzley to the rock-breaker floor. Most gold ores will yield only a portion of their contents to the simple amalgamation process described above, because some of the precious metal is tied up in combination with sulphides and baser metals. The values that are in this form are generally saved by con-

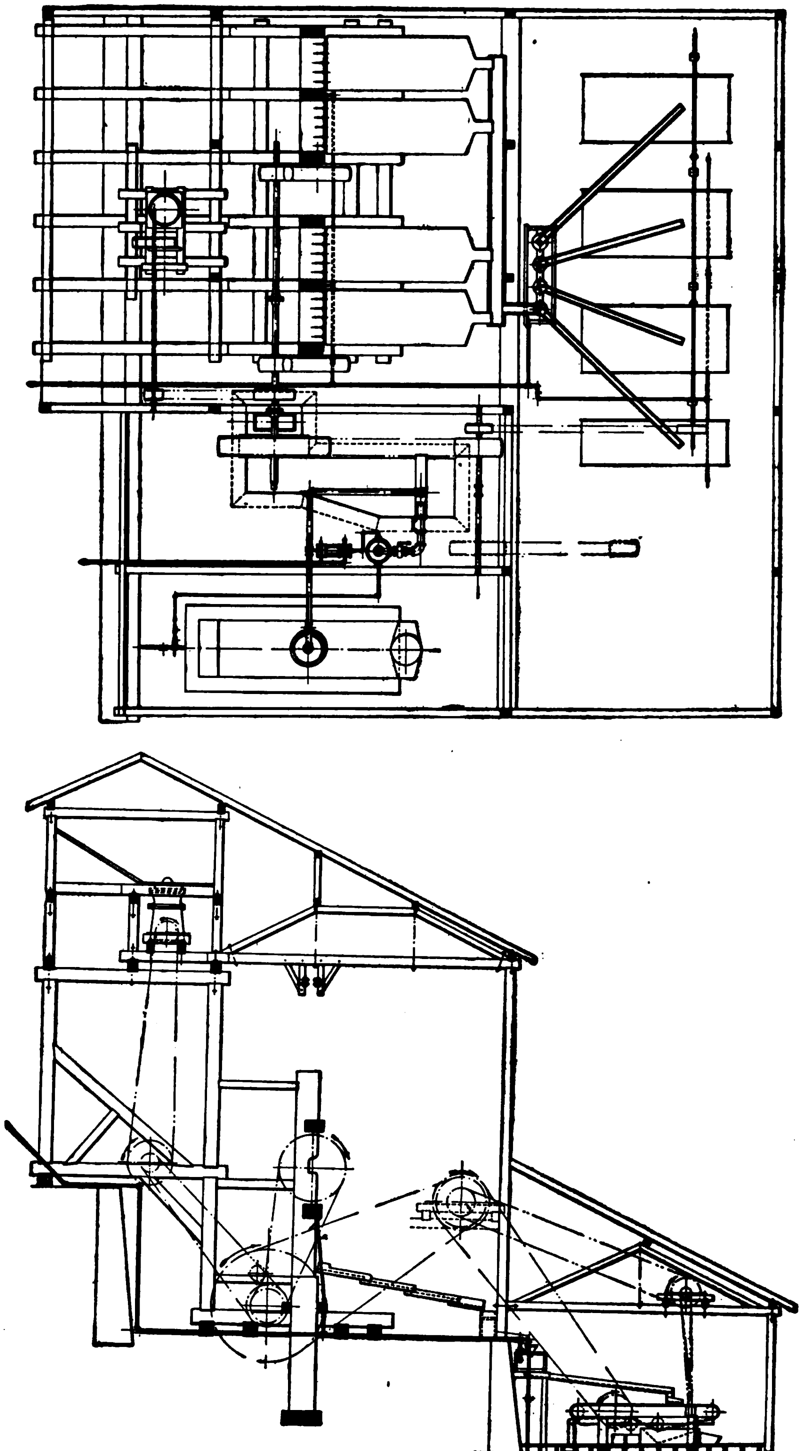


FIG. 82. IMPROVED 20-STAMP MILL.

centration. The vanning machine is the best for this purpose, and it is now more extensively used than any other machine.

This mill is adapted for silver and other ores requiring fine crushing, by dispensing with the amalgamating plates.

Outline of Plant and Process of Gold Mining in the Black Hills.

The crushing is done by means of rock breakers and stamps. The breakers reduce the coarse ore to a size suitable for the stamps. The ore, arriving at the highest level of the mill (the ore-floor) in mine-cars, is discharged from the side or the bottom of the car (dumping and bottom-discharge cars being both in use) over grizzlies to the crusher-floor; or it goes directly to the crusher-hopper. The small ore-particles, passing through the grates of the sizing-screen, and the coarse ore (which has been reduced in size by the crushers), both drop into the same ore-bin, which reaches down to the cam-floor. Here a number of chutes deliver it to the automatic feeders, each of which discharges its contents continuously into the mortar to which it belongs. Here the ore is pulverized by stamps (five in each mortar) lifted at regular intervals by corresponding cams, which are keyed to a cam-shaft, placed in front of the battery on the cam-floor. Water is fed continuously into the mortars, and forms, with the ore, a liquid pulp, which passes through a screen at the front on to and over the apron-plates on the lower floor of the building. The Caledonia mill has blankets on the lower end of these plates to catch any coarse, heavy particles. In the other mills the pulp passes directly from the apron-plates to the mercury-traps and through them on to sluice-plates. From the traps, placed at the end of these, the pulp runs into one main sluice which may again have one or more traps before the pulp is finally allowed to run to waste.

Thus the entire process of passing the auriferous coarse rock from the ore-floor to the final discharge, at the end of the main sluice, is an automatic one.

Battery amalgamation is used to extract the gold. It begins in the mortar, where mercury is added at intervals (while the continuous fine crushing with the stamps is taking place) and ends on the apron-plates, where nearly all the amalgam not retained by the inside amalgamated copper plates is collected daily, any deficiency in the collect-

ing mercury and amalgam on the plates being supplemented by the various traps.

As the mills on the "belt" have to treat low-grade ores, it is necessary to their profitable operation that large amounts should be put through as rapidly as may be, and that, at the same time, as much gold as possible should be saved by simple means. To effect this, a compromise is made between the two extreme methods of gold-milling. One of these aims at extracting as much gold as possible in the battery at the expense of capacity; the other, by amalgamating outside of the battery, increases the crushing capacity, but requires a number of expensive operations to recover the gold. In the Black Hills, amalgamation is carried on both inside and outside the battery, thus combining the simple way of recovering the gold from the first method with the large capacity of the second. The aim is to crush rapidly to the desired fineness, and arrange the amalgamation so that it shall be adapted to the large amount of pulp produced.

Crushing and Briquetting Plants.

Among the many points to be taken into consideration in designing a modern rock crushing plant, one of vital importance is the

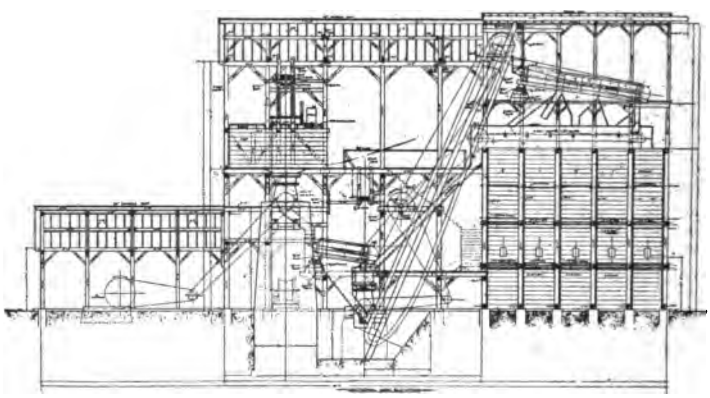


Fig. 83. Crushing Plant.

arrangement of the machinery and the use of appliances which reduce to a minimum the employment of labor in handling material and operating the plant. In the production of road material it is essential that the material be properly screened, as a road-bed is

built up with layers of different size stone. Railroads require the ballast to be screened, and, as screening enhances the value of the product, it is economical in all cases to employ the most efficient screening machinery.

Elevators and conveyors are generally required when bins are used for storage.

Hoisting rigs, skips, or automatic dump cars are very often advantageously employed in the conveying of stone from the quarry to the mill.

A crushing plant of the Carbon Limestone Co., Lowellville, O., is shown in Fig. 83.

CHAPTER X.

LAYOUT, DESIGN AND CONSTRUCTION OF CONCENTRATING MILLS.

In Fig. 84 is illustrated the plan and elevation of an improved concentrating mill, using a Hancock jig and Richards classifiers. In Fig. 85 a diagram is given showing plan and elevation of an improved concentrating mills using Hartz jigs. Either mill is adapted for coarse concentration of copper or lead ores, with fine grinding for the middlings produced by the jigs and subsequent fine concentration on tables and vanners.

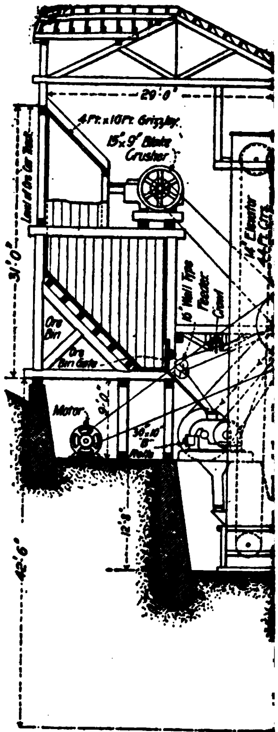
Both of the plants illustrated in this chapter are up-to-date and model mills but are, of course, subject to various modifications to suit variations in the ore to be treated.

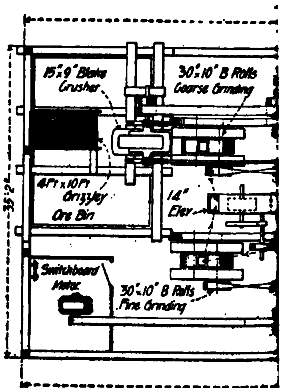
Attention is directed to the difference in the two mills brought about by the use of the Hancock jig and Richards classifier. In the Hartz jig mill four revolving screens and a single cone classifier are used to separate the material into various sizes so that it can be properly handled on eight 3-compartment Standard Hartz jigs.

By referring to the mill using Hancock jigs the reader will note the simplicity and simple arrangement of the machinery, which, on account of the Hancock jig being used, only requires one screen to return the oversize to secondary rolls. The fine material from the screen which determines the maximum size of material to be jigged goes to a Richards annular vortex classifier, which has been designed for use in connection with the Hancock jig and which makes a classification separating material finer than 30-mesh for treatment in the fine concentration section. The other product from the classifier, which ranges from the size perforations on the screen down to 30-mesh, forms the feed to the Hancock jig.

On account of only one Hancock jig being used in place of numerous Hartz jigs it necessarily cuts down the floor space in the mill. These features make it possible to build a mill as much as 30 per cent. lower in cost than for a mill using the required number of screens and Hartz jigs.

Level of Ore Car Track
32'10"
7'6"
24'8"
4 Ft. x 10 Ft Grizzley
34'0"


29'0"
4 Ft. x 10 Ft. Grizzley
15"x9" Blake Crusher
Level of Ore Car Track
31'0"
Ore Bin
Ore Bin Gate
14" Elevator
Motor
30"x10" "B" Rolls
12'8"
42'6"


15"x9" Blake Crusher
30"x10" B Rolls Coarse Grinding
4 Ft x 10 Ft Grizzley Ore Bin
14" Elev.
Switchboard
Motor
30"x10" B Rolls Fine Grinding
35'2"

Fine Concentration Mill: Tremain Steam Stamps and Overstrom Concentrating Tables (Fig. 86).

1 No. 1 Gates Breaker, Style "D."
1 No. 2 Gates Elevator.
2 Tremain Steam Stamps with Feeders.
2 Overstrom Concentrating Tables.
1 10-H.P. Vertical Engine for Crusher.
1 5-H.P. Vertical Engine for Overstrom Tables.
13 Feet Shafting, 3 Pulleys, 3 Pillow Blocks, $1^{15}/_{16}$ inch.
6 Feet Shafting, 3 Pulleys, 3 Pillow Blocks, $2^{15}/_{16}$ inch.
38 Feet 7-inch, 4-ply Rubber Belting.
36 Feet 7-inch, 4-ply Rubber Belting.
42 Feet 6-inch, 4-ply Rubber Belting.
38 Feet 6-inch, 4-ply Rubber Belting.
58 Feet 3-inch, 3-ply Rubber Belting.
1 Set of Building Bolts.
All Pipe and Fittings for Steam and Water Supply for Boiler, Injector, Pump, Engines and Stamps.
1 50-H.P. Portable Boiler, on Skids.
1 Injector.
1 Boiler Feed Pump.
4 Extra Boss Heads, cast iron.
8 Extra Shoes, forged steel.
8 Extra Dies, white iron.
2 False Bottoms for Tremain Mill.
12 Extra Sets Screens.
2 Extra Sets Screen Frames.
10 Pounds Imperial Packing.
1 Square Yard Rainbow Packing.

Elmore Vacuum Process at Broken Hill, New South Wales.

The tailings for treatment are trammed to a range of bins at the back of the plant, and from thence such portions as require grinding are transferred by Challenge Feeders on to conveyor belts to twelve grinding pans, where they are ground wet to pass 30-mesh screens. The whole product from the twelve grinding pans pass by gravity to six improved sizing screens, the undersize from these screens passing direct by belt bucket elevators to the Elmore plant. The oversize from the six screens is taken by a belt-bucket elevator

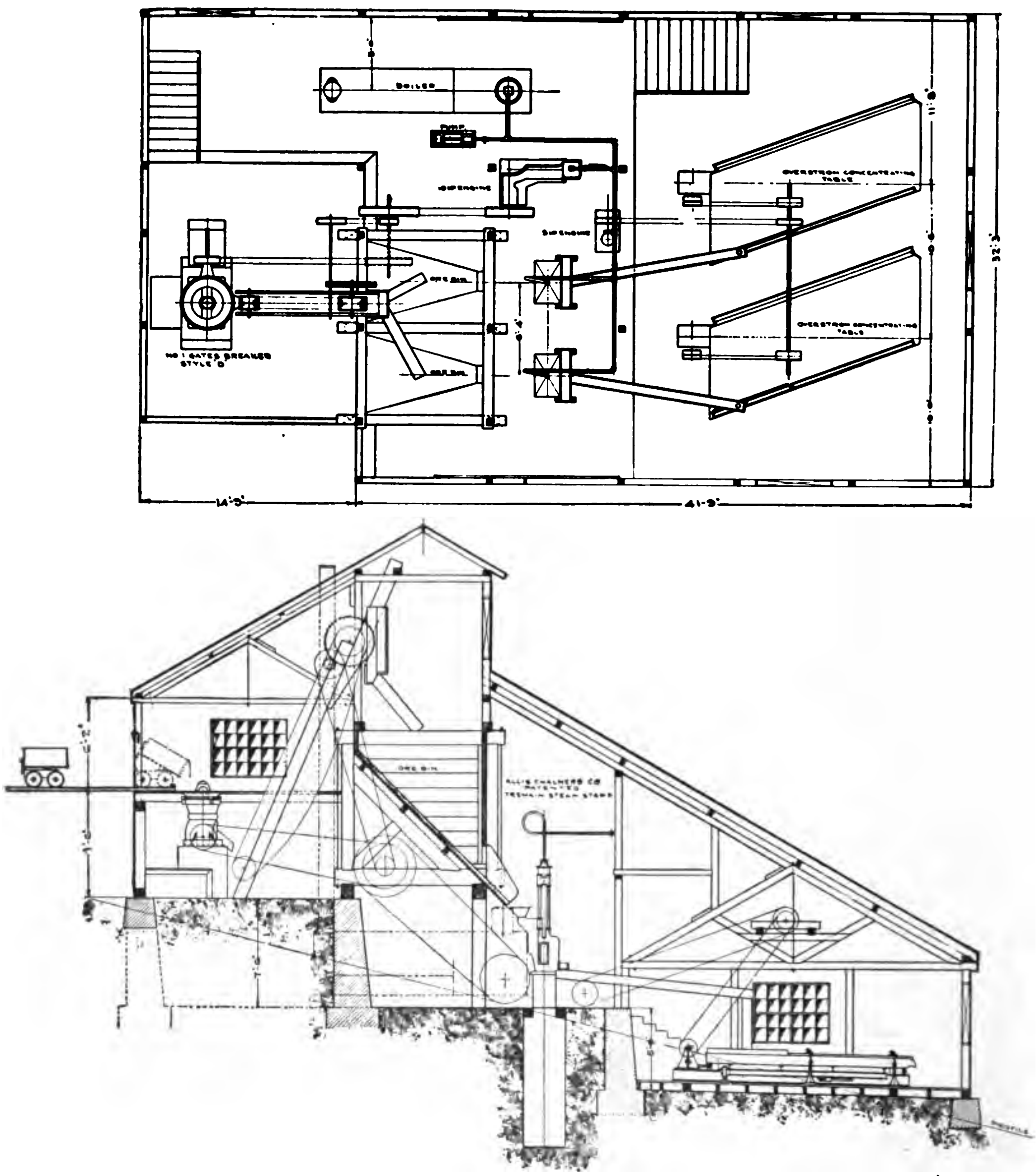
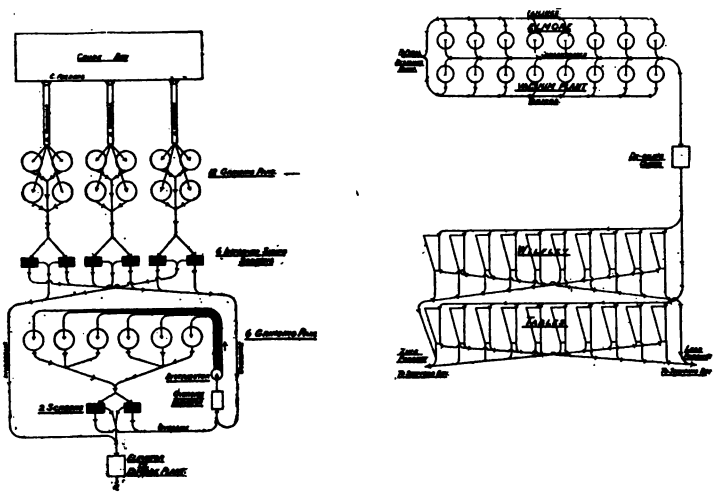


FIG. 86. FINE CONCENTRATION MILL.

to a distributor, which divides it equally between six additional grinding pans; the whole pulp from these last six pans passes to two screens, the undersize from which joins the undersize from the first six screens, the oversize being returned to the last six grinding pans.

The attached "flow sheet," Fig. 87, will make the details of this grinding section quite clear.

The whole of the pulp from the eighteen grinding pans referred



FIGS. 87–88. ELMORE-VACUUM PROCESS.

to above passes through an automatic distributor, by which it is divided into sixteen equal parts, one part going to each unit of the Elmore plant.

The final residues from the Elmore concentrators pass by gravity, and quite automatically, on to specially designed conveyors, and are thus transported directly to the dump.

The concentrates from the Elmore machines consist principally of the mixed sulphides of zinc, lead, and silver, together with some sulphide of iron, and it has been found more profitable to separate the zinc and lead by a subsequent treatment (which will be described later) than to sell the mixed concentrate.

The bulk of the material thus far operated upon by the Zinc Corporation has an approximate average assay of—

Zinc	20 per cent.
Lead	5.75 per cent.
Silver	8 ozs. per ton of 2,240 lbs.

The mixed concentrates produced therefrom have an approximate average assay of about—

Zinc	43 per cent.
Lead	11 per cent.
Silver	17 ozs. per ton of 2,240 lbs.

These mixed concentrates are allowed to drain as free from water as possible, and are then, by means of push conveyors, transported to furnaces, where they are dried by artificial heat and raised to a sufficiently high temperature to drive off the small quantity of oil which they contain. The de-oiled concentrates, after cooling, are mixed with water and treated on twenty Wilfley tables in the usual manner, the results of this operation being a final zinc concentrate having an approximate average assay of—

Zinc	46.5 per cent.
Lead	7.25 per cent.
Silver	16 ozs. per ton of 2,240 lbs.

and a lead concentrate having an approximate average assay of—

Lead	58 per cent.
Zinc	15 per cent.
Silver	39 ozs. per ton of 2,240 lbs.

The grade of the final residues depends to a great extent upon the more or less oxidized condition of the values in the material operated upon, but the following may be taken as fairly representative:

Zinc	3.5 per cent.
Lead	2.2 per cent.
Silver	2.2 ozs. per ton of 2,240 lbs.

Direct determination has shown a substantial part of these final residues values to be present in the form of oxidized compounds.

The actual recovery of values secured by the Elmore plant may be taken as follows:

Zinc	90 per cent.
Lead	73 per cent.
Silver	85 per cent.

Some loss of these recovered values naturally takes place in the separation of the zinc and lead on the Wilfley tables plant. The exact amount of this loss is not known to the writer.

The sulphuric acid used in the plant is manufactured in the Zinc Corporation's own acid works; it is of the usual commercial quality. The consumption of acid varies to some extent with variations in

the material of the different dumps treated, and may be taken at 20 lbs. per ton as a maximum and 10 lbs. per ton as a minimum.

The oil employed is Texas fuel oil, the consumption being at the rate of 6 lbs. to 8 lbs. per ton of material treated.

The ratio of concentration bears a relation to the grade of material treated, but may safely be assumed on the average to be about 2.5 tons into 1.

The whole plant was designed with a view to economizing manual labor, and in this respect also has been very successful in regular operation.

Exclusive of the labor required for the power plant and crushing section there are engaged—One man for the separator and vacuum pump floors, one man for the mixer floor, one man at the discharging floor. The men work three shifts per twenty-four hours.

It will be seen, therefore, that the amount of labor required for the control of the Elmore plant is extraordinarily small.

The plant is regularly handling from 16,000 to 17,000 tons per month, and producing therefrom 6,000 to 7,000 tons of concentrates per month (Fig. 88).

The average daily capacity of each unit of Elmore plant is 40 to 45 tons; but the unit of capacity has been actually proved as high as 70 tons per twenty-four hours.

The Zinc Corporation installed the plant on the assumption that it would have a capacity of 500 tons per twenty-four hours, that it would produce a concentrate containing about 41 per cent. zinc, and yield an extraction of about 80 per cent. zinc.

As will be seen from the above, regular work over a long period of time has proved the original estimates to have been much too conservative both as to capacity, grade of concentrates, and percentage extraction of values.

CHAPTER XI.

LAYOUT, DESIGN AND CONSTRUCTION OF COPPER SMELTERS.

Since we have described in detail the layout of several metallurgical plants, which, in principle, are very similar to copper plants, we will in this instance illustrate a copper smelting and converting plant without giving an additional description as the cuts are self-

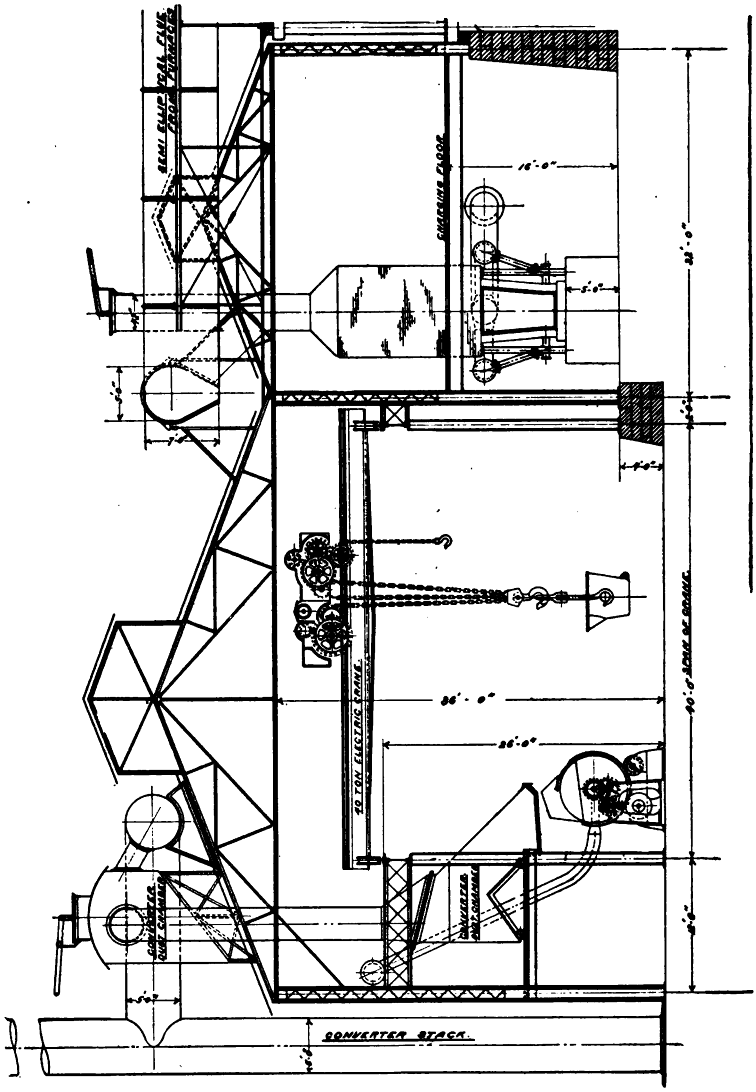


FIG. 90. COPPER SMELTING AND CONVERTING PLANT. ELEVATION.

explanatory. Fig. 89 shows the plan, Fig. 90 the elevation of a smelting and converting plant.

CHAPTER XII.

LAYOUT, DESIGN AND CONSTRUCTION OF MACHINE PEAT FACTORIES.

The bulkiness of the cut peat, its comparatively small fuel value per unit of volume, its dependence on favorable weather conditions for drying and the ease with which it crumbles to pieces, are objectionable qualities which are overcome, at least to a great extent, by mechanical treatment. By the mechanical treatment the raw peat from the different layers of the bog is more or less thoroughly mixed and pulped, depending on the methods and machinery used. The more thorough these processes are carried out, the more solid is the fuel obtained and the better its quality. By pulping the peat, the cell walls are broken up and the moisture more easily evaporated. Thoroughly pulped peat is comparatively compact and the hollow spaces which it contains are very small. When such peat is exposed to the air the surface dries comparatively quickly and a kind of skin is formed.

The pores in this skin close during the rainy and damp weather, through the swelling up of the peat, preventing the moisture from entering the interior. In dry weather the pores open up again and the drying continues at practically the same content of moisture which the piece had before the rain, contrary to the cut peat, which easily becomes saturated with moisture.

The methods used for the manufacture of machine peat differ considerably and depend on the nature of the peat and on local conditions. The principal difference is that, in some methods, which otherwise may differ in details and machinery used, the peat is mixed with additional water and the product obtained afterwards moulded into the desired shape or otherwise treated.

In other methods, which also may differ in details and machinery used, the peat is treated without additional water, and leaves the machine in one or more continuous bands of rectangular cross-sections, and with such consistency that no special moulds are required. This peat is called machine-formed peat, or in many cases only machine peat.

MACHINE PEAT MANUFACTURED WITH ADDITIONAL WATER.

(*a*) **Manufactured Without the Aid of Machinery.**—In some localities, when only a small quantity is desired or no capital available, the peat is treated without any special machinery either by manual labor or with horses.

In the former case the work is carried out in the following manner: One man digs the peat out of the bog and tramples it, with the addition of water, on the bottom of a trench to a thick porridge, which he later shovels into a bin, from which another man loads it into a wheelbarrow and transports it to a drying field, where it is dumped into moulds.

In the latter case a rectangular trough made of boards is erected about 3½ ft. below the surface of the bog. The peat in the neighborhood is thrown down into this trough and water added. A horse ridden by a man or boy tramples and mixes the peat, which, when ready, is loaded into a cart and drawn by the horse to the drying field.

(*b*) **Manufactured with the Aid of Machinery.**—The machine mostly used consists of a vertical cylinder or a horizontal half cylinder, in which a shaft provided with knives placed in the form of a screw thread rotates. The raw peat, together with the water, is fed in at one end. By means of the rotating knives the peat is more or less thoroughly mixed and pulped and moved towards the other end of the cylinder, where it leaves the machine as a homogeneous porridge. This peat porridge is at smaller plants shovelled directly into wheelbarrows or trucks and brought to the drying field. At larger plants it is first brought by means of elevators or conveying apparatus of some kind to a large bin, from which it is conveniently tapped as required into dumping cars and brought to the drying field.

The work of manufacturing machine peat is properly divided into four different processes, which are as follows:

1. Digging the raw peat out of the bog and transporting it to the plant.
2. The mechanical treatment of the peat.
3. Transportation to the drying field and laying out for drying.
4. Drying work.

The power required for the operation of the machinery used for

treating the peat is furnished at smaller plants by animal power, and at larger plants by mechanical motors, usually a locomobile, but gasoline and electric motors are also used.

Arrangements at Smaller Plants.

The general arrangements at such plants is shown in Fig. 91. The raw peat is dug from the trench *a*, and thrown into a bin *b* placed at the side of the pulping machine *c*. From the bin it is fed into the machine with the additional water supplied by the pump *e*. Sometimes the bin *b* is omitted and the peat dug out thrown directly into the machine. The pulped peat runs into a bin *d*, from which it is loaded into wheelbarrows or cars and transported to the drying field. The surface of the bog is generally too soft to allow a horse to walk comfortably; boards are therefore laid down as shown in the figure. The shaft is brought to rotate by means of a simple

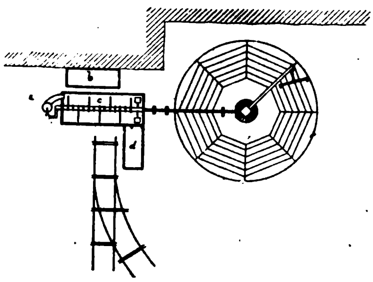


Fig. 91. General Arrangements at a Small Peat Plant.

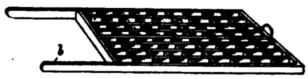


Fig. 92. Peat Mold.

bevel gear in the same manner as a threshing machine, and the pump *e* is brought into operation at the same time by a crank placed at the further end of the shaft.

These small plants are either placed on the bog and moved at the rate the bog is worked out, in order to reduce the transportation of the raw material to a minimum, or else placed convenient to the drying field, when the raw peat has to be transported to the plant. In this latter case the pulped peat mass is generally conveyed to a bin, from which it can be conveniently tapped into dumping cars or carts.

The pulped peat is dumped on the drying field into large moulds (see Fig. 92), divided into rectangular sections of desired dimensions. By means of wooden scrapers the peat mass is levelled and

made to fill up the mould, any excess being scraped into the next mould. After a few minutes, generally ten to twelve, the excess of water added has run away and the peat bricks are sufficiently solid to allow the removal of the mould. The legs *b* at the back of the mould are of such length that the shape of the peat bricks is not impaired when the mould is lifted up in front and drawn forward. When sufficiently dry, the peat bricks are turned and later piled in heaps. With four to six men and one horse a production corresponding to 5–8 tons air-dried peat per day can be obtained.

This method is the one best adapted for a small production. The machinery employed is simple and inexpensive, and the peat fuel produced fairly well pulped and mixed.

Arrangements at Larger Plants.

The general arrangements, methods of working machinery employed at such plants differ considerably in different localities, and in order to better illustrate these different arrangements, individual descriptions of some of the more important plants are given.

Sparkaer, Denmark.—The peat bogs at Sparkaer have been worked for many years and at present nine different peat plants are in operation. The season during 1907 was exceedingly wet and unfavorable, but nevertheless 14,645 tons of peat fuel were produced.

The different plants at Sparkaer are all of similar construction, but of different capacities. The methods used for digging, transportation and drying are also identical. The plants and methods used at Sparkaer are under the prevailing local conditions very practical, and their introduction is largely due to Mr. M. Rahbek.

The Okaer Plant.—This is the largest plant and was built on solid ground close to the margin of the original bog, which, however, since that time has been worked out to a considerable extent. Level sandy plains, free from trees or other obstacles to the wind and in the immediate vicinity of the plant, are used for drying fields. The drying conditions are, therefore, exceedingly favorable, which largely accounts for the success of these plants. During 1907 the production from the Okaer plant was 3,850 tons peat fuel. The capacity of this plant is about double this amount, but at present it is not worked to its full capacity.

Fig. 93 shows the general layout of the plant.

1. **Digging and Transportation of the Raw Peat.**—The bog is

sufficiently drained, contains well-humified peat and is free from roots, trunks and stumps of trees. The upper layer to a depth of some four inches is thrown into the previous working trench, which

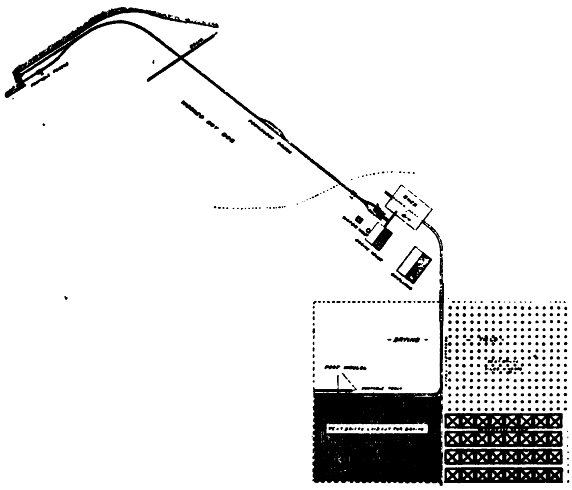


FIG. 93. LAYOUT OF PEAT PLANT.

at the rate the bog is worked out is brought under cultivation. At present the bog is worked to a depth of 8–9 ft.

The bog is connected with the stationary plant by a railway, which is gradually increasing in length. Close to the part of the bog which, at the time, is being worked, a side track is laid down so that the bog is attacked from two tracks about 25 feet apart. From each track a trench 25 feet wide is worked out. The rails are laid on old railway ties, which are placed close together on the bog and a little above the water level, in order to enable the horses, which are used for the transportation of the raw peat to the plant, to walk comfortably. The peat is dug out with the spades shown in Fig. 94 and loaded on wooden cars which can be tilted either to right or left and hold about 4 cu. yds. of raw peat.

FIG. 94. SPADES.

Each car is hauled by one horse between the bog and the plant and is attended to by a boy. For digging the peat and holding it on the cars six men are employed, and for the transportation, two horses attended by two boys. One extra man cleared away the surface layer and attended to the road beds.

2. **Mechanical Treatment of the Peat.**—The mixing and pulp-

ing of the raw peat is done in a box 25 ft. long and about 2 ft. wide and deep (see Fig. 95), in which the shaft supplied with the usual knives rotates at a speed of about 50 revolutions per minute. The necessary water is supplied by a centrifugal pump to a tank, from which it is brought to the different parts of the machine and regulated by the man attending to the feeding. This man also attends to the tilting of the cars loaded with the raw peat. A great part of the load falls, when the car is tilted, directly into the machine, but that which is left has to be raked or shovelled into it. Tracks are laid on both sides of the machine, so that when one car is emptied

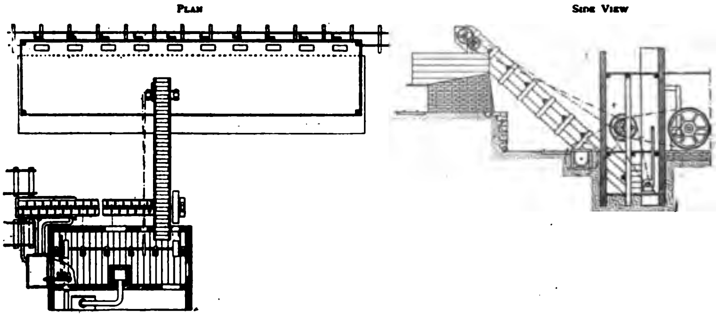


FIG. 95. PEAT PLANT AT OKAER, DENMARK.

a full car is brought up on the other side and the empty one hauled back to the bog. The pulped peat, which has the consistency of porridge, runs from the machine to an elevator which conveys it to the loading bin, placed at such a height above the ground that it can conveniently be tapped into cars. The elevator consists of a wooden trough provided at each end with a shaft supplied with two sprocket wheels and chains. The chains are provided with pallets which run against the bottom of the trough and scrape the peat porridge along. The upper shaft is also provided with a pulley which is operated by a belt from the engine. The power required, is furnished by a 20-H.P. steam engine attended by one man.

3. **Transportation to the Drying Field and Laying Out for Drying.**—The peat porridge is loaded into steel dumping cars holding about ⅔ cu. yd. The bin is provided with holes in the bottom at suitable distances apart, which are opened or closed by a simple lever arrangement, permitting a very rapid loading of the cars. The time required to load twelve cars, transport them to the drying field on an average ¼ mile distant, unload and transport them back to the bin occupies only 10–12 minutes.

A permanent track is laid from the bin through the center of the drying field, dividing it into two parts. The peat is first laid out on one side of this track by means of a portable track some 800 ft. in length, and when the whole area is covered, this track is moved over on the other side and the work continued. As a rule, the peat has ample time to dry before the same field is needed again. The portable track is made in sections, which are easily disconnected, moved and again put in place by the men attending to the moulding of the peat bricks. For this process, one man is needed for every 25,000 peat bricks produced per day. The production last summer was between 80,000 and 100,000 bricks per day, and four men were, therefore, employed on the drying field. The sections of the portable tracks are connected by means of sliding shoes, which are moved on the rails of one section when it is to be removed and slid over to cover the joints when it is desired to put the sections together.

The moulds used are made of boards and are divided into 55 rectangular spaces $10 \times 5.6 \times 3.2$ ins. in dimensions. The front is supplied with two handles and the back with two legs, 20 ins. long, made of round iron. In order that the shape of the bricks may not be impaired, the mould is lifted up in front and drawn forward resting on these legs. The peat porridge is loaded at the bin on a train of twelve cars, which is hauled to the drying field by two horses attended by a man and a boy who also attend to the loading. Each car contains enough material to fill three moulds. Since the length of two cars is equal to that of three moulds, the train when first brought up to the moulds, discharges only every other car: it is then moved forward a distance equal to its own length, and then discharges the remaining full cars.

The peat mass is levelled by means of wooden scrapers and made to completely fill the moulds. As soon as the moulds in front of one section of the track are filled, this section is moved back a distance equal to the depth of these and when the peat is sufficiently dry to retain its shape, which usually takes 10–12 minutes, the moulds are also moved the same distance. No time is therefore lost in waiting, as the men have sufficient time to remove the sections of the track and the moulds while the cars are being reloaded and again brought back to the drying field. The last section to be removed is the curve connecting the portable track with the permanent one. This curve is connected by simply putting it on top of the straight rails and is done in a very short time.

4. **Drying.**—When the peat bricks are sufficiently dry to be handled they are raised on edge, resting against each other, and turned so that the sides which previously were underneath, are now most exposed to the air. They are left in this position until sufficiently dry to be piled in heaps. These heaps are made conical, 5–6 ft. in height.

The drying work is generally done by women and children by contract. A skilled woman can raise and turn 6,000 bricks per hour or pile up 2,500 in such heaps.

Under favorable weather conditions the drying down to some 25 per cent. moisture is accomplished in about three weeks, but usually a longer time is required.

The peat bricks when dried are generally loaded on large wagons, brought to the nearest railway station about 1½ miles from the bog, and loaded on railway cars. If they have to be stored at the plant they are piled in large stacks, but the cost of stacking has then to be added to the cost of production and stacking is, therefore, avoided if possible. At Sparkaer the working season generally lasts about 115 days and starts as soon as the frost has sufficiently left the ground.

APPROXIMATE COST OF PRODUCTION.

During the season 1907, which as previously stated was exceedingly wet and short, the daily production (10½ hours) averaged 86,000 peat bricks. Each brick weighs 1.1 lbs. when air-dried. The daily production was, therefore, 47.3 tons.

The number of men employed was:

6 men digging the peat out of the bog.

2 boys and 2 horses for transportation of the raw peat to the plant.

1 man clearing the surface of the bog.

1 man attending to the pulping machine.

1 engineer.

1 man, 1 boy, and two horses for transportation of the pulped peat to the drying field.

4 men on the drying field.

Total—14 men, 3 boys and 4 horses.

The men were usually paid by contract, but on an average they were paid to make \$1.35 to \$1.65 per day, or say \$1.50, and the boys 75 cents. Assuming that the cost of a horse is 60 cents a day, the total cost would be:

For digging, pulping, transportation, and laying out.	Per Day.	Per Ton.
14 men at $1.50 per day	$21.00	44.4
3 boys at $0.75 per day	2.25	4.7
4 horses at $0.60 per day	2.40	5.0
For drying work.		
5 cents per 1,000 pieces		9.0
For loading and carting to railway, approx.		25.0
For fuel, oil repairs, etc., say		11.9
Total		100.0

To this must be added interest, depreciation, and general expenses, probably amounting to some 50 cents per ton, making the total cost about $1.50 per ton.

The price obtained F.O.B. Sparkaer station was $1.95 per ton. The fuel has a well-established market, and was easily disposed of.

In Denmark the method described above is the one mostly used and in localities where drying conditions are favorable and the peat well humified, this method is one of the best.

Stafsjo, Sweden.—The method used at Sparkaer was introduced at the above place in 1899. Two plants were built, each having a capacity of 30–40 tons per day. The available drying fields were not large enough, however, and the production was decreased to some 25 tons per day for each plant. The surface of the bog was used for drying field. Each plant was run with a 8-H.P. gasoline engine.

Herning, Denmark.—The methods and machinery used at Herning differ considerably from those used at Sparkaer. At Herning the surface of the bog is used as a drying field. The bog contains well-humified peat of good quality and is worked to a depth of 7 to 8 ft. The machinery used for the treatment of the peat is mounted on a movable platform, and is moved on the edge of the working trench at the rate the work proceeds. The transportation of the raw material to the plant is, therefore, avoided.

The raw peat is dug out from a trench *k* about 30 ft. in width, thrown into the long screw conveyor *a* (see Fig. 96), where water is added and conveyed to a Dolberg peat machine *b*. This machine consists of two horizontal screws, which rotate against each other, mixing and kneading the pulp mass. From this machine the peat mass is conveyed by a vertical screw elevator *c* to a large bin *d*, placed above the platform. The power required is furnished by a 16-H.P. locomobile *f* mounted on the same platform as the peat

machine, bin and elevator. The platform is provided with wheels and moves on rails *g* laid down at the edge of the trench. These rails are taken up and laid down in front of the plant at the rate the trench is worked and when the plant needs to be moved. On the side of the plant a portable track *h* is laid down for the transportation of the peat mass to the drying field. This track is made

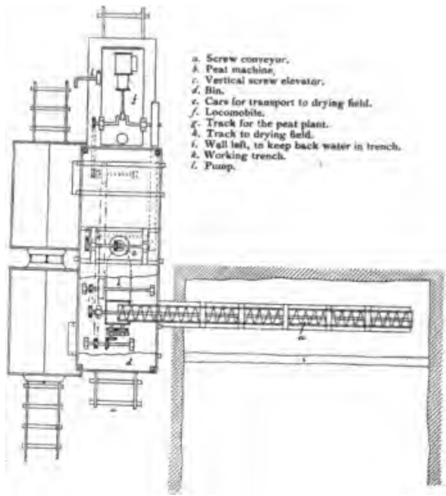


FIG. 96. PEAT PLANT AT HERNING, DENMARK.

in sections which are easily moved when the end of the working line is reached and the plant has to be moved back and another trench started.

The peat porridge is tapped from the bin *d*, which has two spouts into two large wooden cars *e*.

On one side of the drying field a permanent track is laid down, and by means of a portable track any part of the drying field is reached.

On each side of this portable track two large iron moulds are used. These moulds are made of ⅛-in. sheet iron and divided into 500 rectangular spaces about $7.2 \times 3.6 \times 2$ ins. in dimensions. They are too heavy to be moved by hand labor, and a special mechanical lifting and moving apparatus is therefore used for this purpose.

Aamosen, Denmark.—The bog worked at this place is not drained and the method of working is, therefore, different from these previously described. The mixing and pulping machinery together with elevator and locomobile are placed on a barge floating in the working

trench and are moved forward at the rate the work proceeds. The elevator conveys the peat mass to a bin movable on rails laid down on the edge of the trench. From this bin the peat porridge is tapped into dumping cars and transported to the drying field, which here is the surface of the bog. The moulds and drying processes used are the same as those employed at Sparkaer.

The construction of the barge used and the arrangement of the machinery which it carries are shown in Fig. 97. When the first

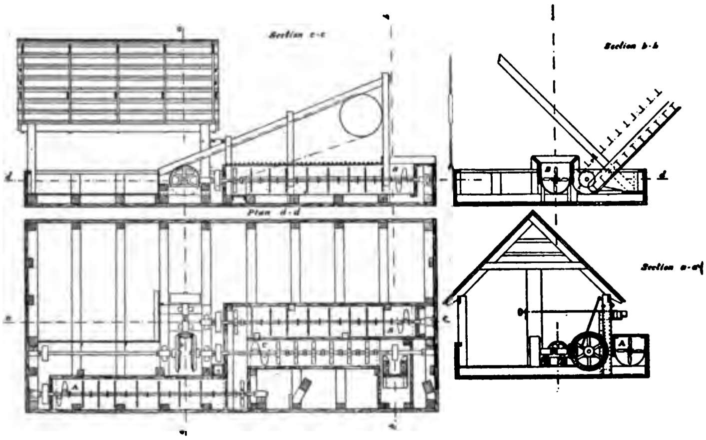


FIG. 97. FLOATING PEAT PLANT AT AAMOSEN, DENMARK.

trench is started, the surface layer is removed and a hole dug of the dimensions of the barge to a depth of about 300 ft. below water level, which is sufficient to keep it floating. The barge is placed in the hole and when the machinery is started the peat first dug out is thrown into the pulping machines *A* and *B*, where water is added. These machines are of the same construction as that described at Sparkaer.

The peat porridge leaving these machines is, in the plant shown in Fig. 97, also put through an additional machine *C*, which delivers it to an elevator. The power required for this plant, which under normal conditions has a capacity of 17 to 22 tons air-dried peat per day of 11 hours, is 41-H.P. furnished by the locomobile. The elevator *D* conveys the peat porridge to the bin *E* (see Fig. 98), from which it is tapped into the dumping cars *F*. A train of six cars is hauled by one horse to and from the drying field. The peat in front and on the side of the barge, is dug out as shown in Fig. 98,

until some four inches above water level, when walls *a* are left to keep out the water while the lower layers are dug out to the desired depth, in this case about three feet below the water level.

When the peat in front of the barge has been removed from such an area that the barge can be moved half its length, the walls *a* are

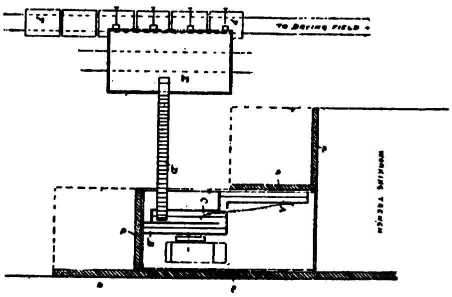


FIG. 98. PEAT PLANT AT AAMOSEN, DENMARK.

dug out to sufficient depth and the barge and bin moved forward this distance. Simultaneously as the peat in front of the barge is removed, the peat on the side is also removed.

The greater distance the barge can be moved in a straight line the better it is, as then less time is consumed in removing tracks and plant. When the end of the working line is reached, the barge has to be drawn back to the beginning and another trench started.

CHAPTER XIII.

LAYOUT, DESIGN AND CONSTRUCTION OF GAS PLANTS.

Fig. 99 shows a cross section of the gas producer house at the Lackawanna Steel Company, Buffalo, N. Y., showing coal and ash handling equipment. The producer used is the Morgan producer built by the Morgan Construction Company, of Worcester, Mass.

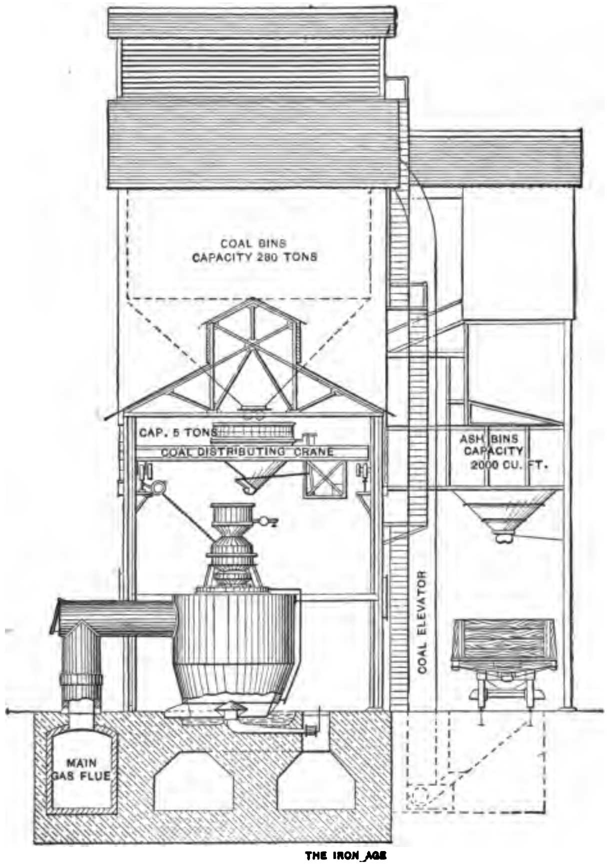


FIG. 99. CROSS SECTION OF A (MORGAN) GAS PRODUCER HOUSE.

Fig. 100 shows one of the most flexible arrangements available for the operation of a producer plant. The coal is brought into the plant in cars. If in hopper-bottom cars, it is discharged upon the

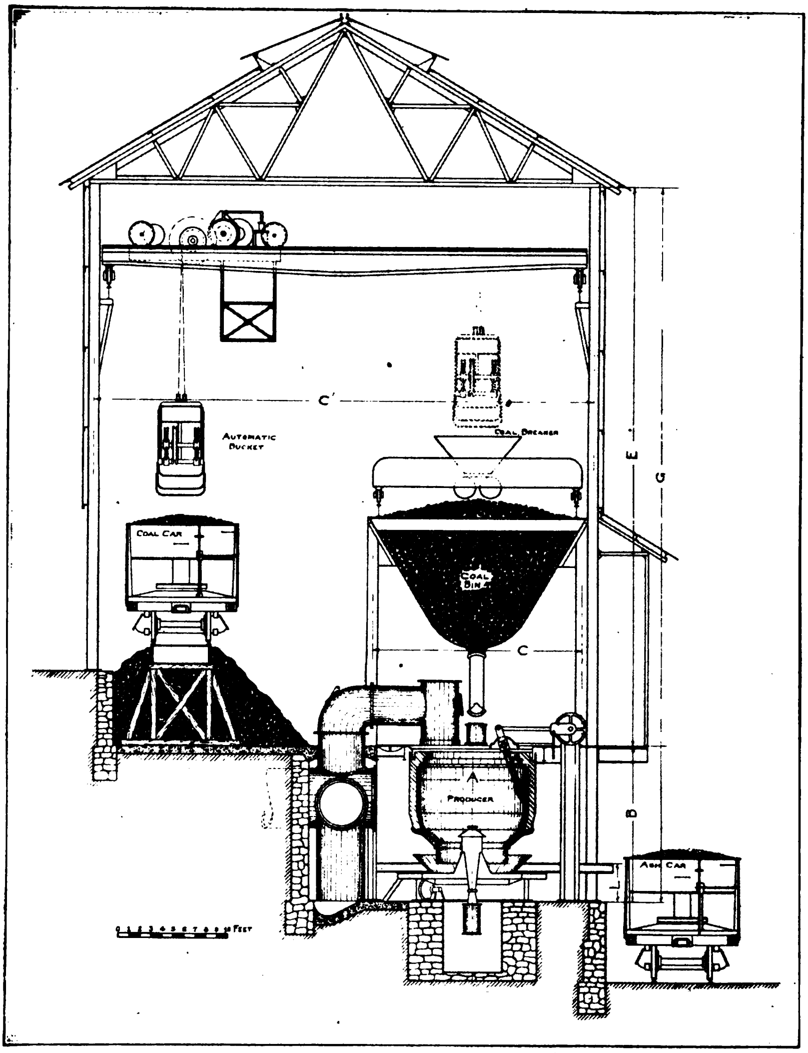


FIG. 100. HUGHES CONTINUOUS GAS PRODUCER PLANT.

floor below, from which position it is handled by means of an automatic bucket; if in gondola cars, adapted to the use of automatic buckets, it is taken direct from the cars, being conveyed by the automatic buckets to the coal breaker carried over the storage bins above the producers. The hopper over this breaker may be carried on weighing scales, so that the coal passing to the coal bins may be accurately weighed. The coal bin shown is of the parabolic sus-

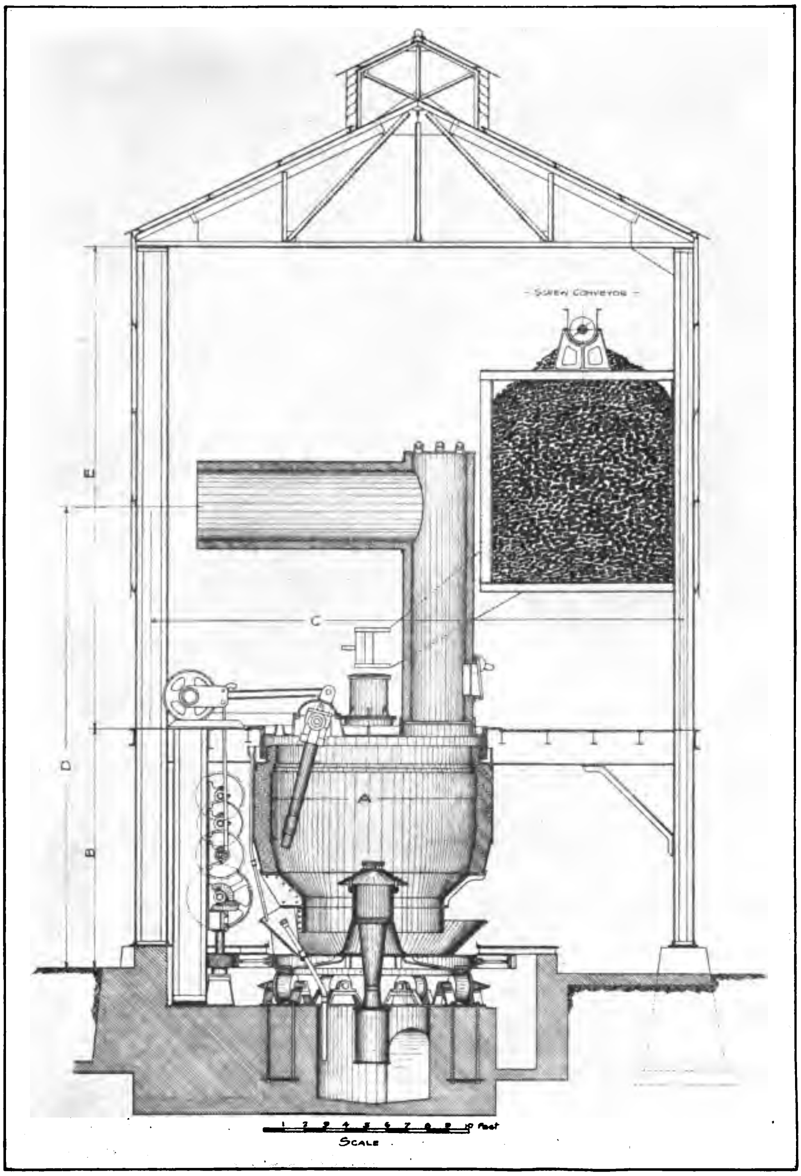


FIG. 101. HUGHES CONTINUOUS GAS PRODUCER PLANT.

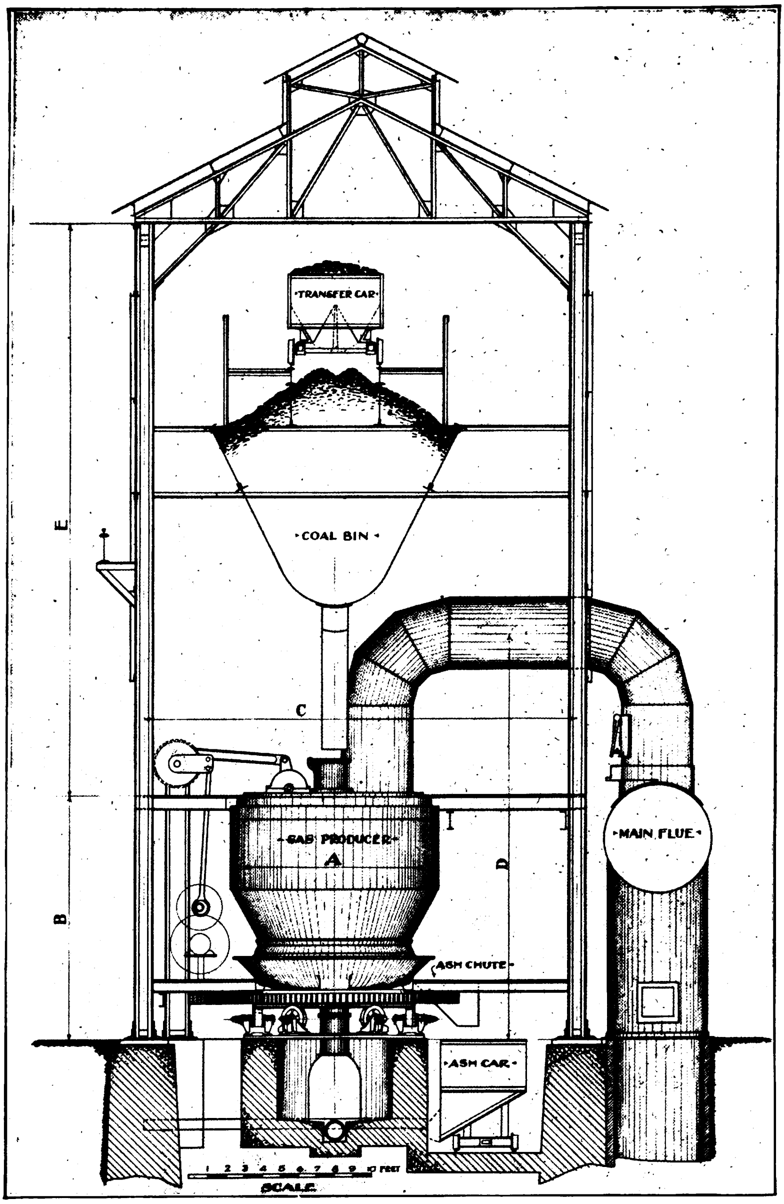


FIG. 102. HUGHES CONTINUOUS GAS PRODUCER PLANT.

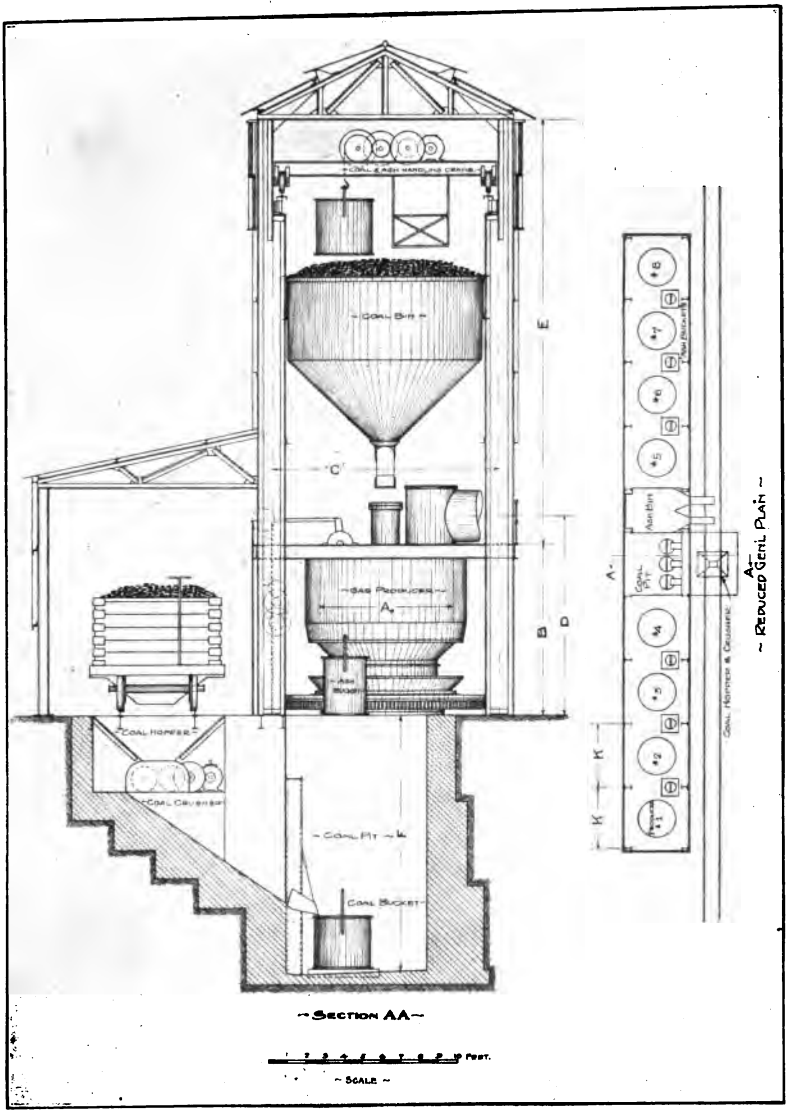


FIG. 103. HUGHES CONTINUOUS GAS PRODUCER PLANT.

pension type and by means of chutes the coal is discharged from this bin directly into the producer. This plant is designed for a side hill location and the ashes are shoveled direct from the producers to the ash cars on the depressed track as shown.

Fig. 101 shows a simple arrangement of producer plant in which the coal is brought in at one end of the building in cars, discharged

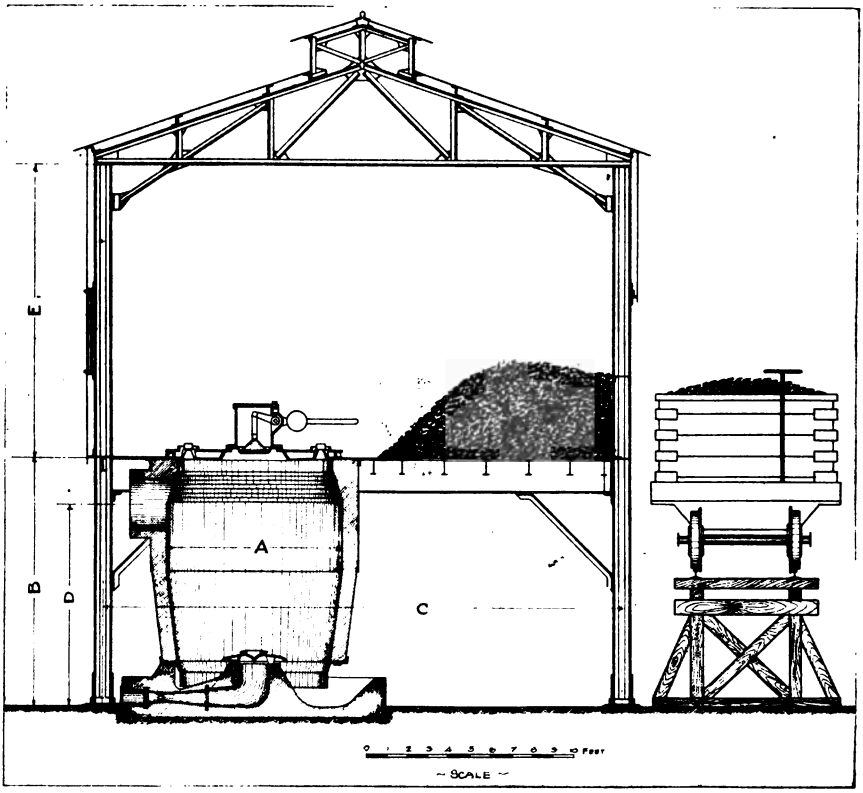


FIG. 104. HUGHES CONTINUOUS GAS PRODUCER PLANT.

into a crusher (not shown in cut), then elevated and conveyed to any part of the producer by means of a screw or other conveyor, the coal being discharged into a bin and thence into the producer through chutes. With this arrangement, special means is necessary for handling the ashes.

Fig. 102 shows an arrangement in which the coal- and ash-handling is done entirely by machinery, the producer being of the self-cleaning type. The coal is discharged from hopper-bottom cars directly into a weighing hopper carried on a traveling crane, and distributed into small bins placed above each producer, these bins being provided with chutes for charging the coal direct into the producers. The producer being of the self-cleaning type, discharges the ashes into its ash hopper, from which they are discharged into an ash car beneath.

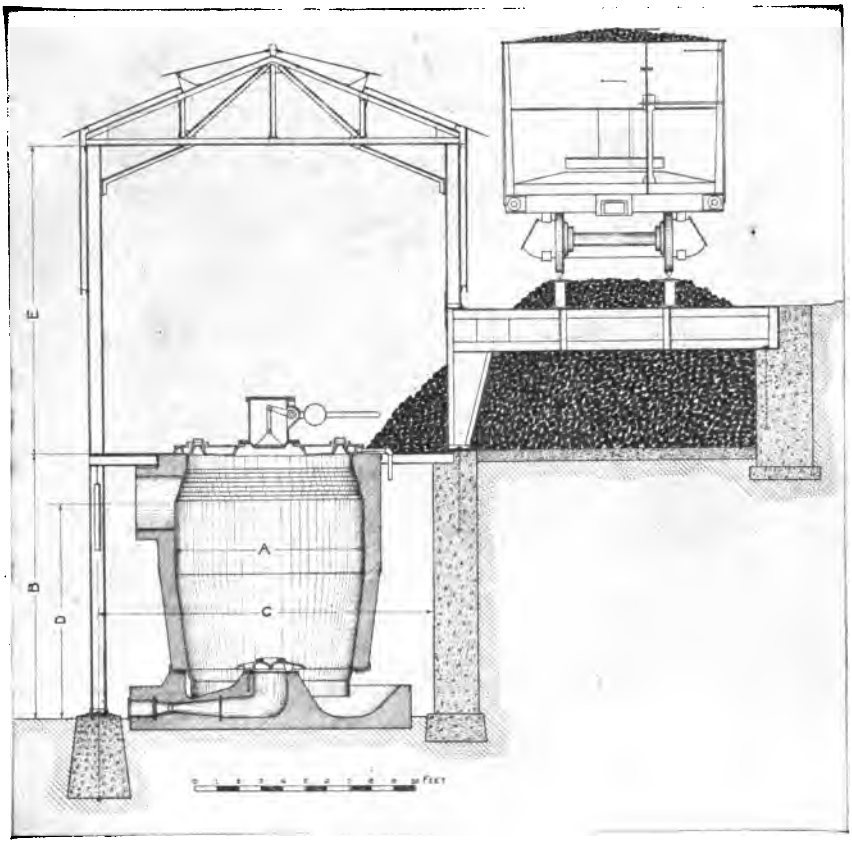


FIG. 105. HUGHES CONTINUOUS GAS PRODUCER PLANT.

Fig. 103 shows a gas producer plant in which the coal and ashes are practically entirely handled by machinery. The only hand labor necessary is that required for taking the ashes from the producer and depositing them in the ash bucket. The coal is discharged into a coal hopper, and passes into a coal crusher, from the coal crusher it is discharged as required into coal buckets. These buckets are elevated by the traveling crane and traverse to the coal tanks or bins into which the contents of the buckets are dumped, bins being placed above each producer.

The ash buckets are placed between the producers in such a position that the ashes may be easily shoveled from the producer to the bucket. The buckets, when filled, are hoisted by the crane and

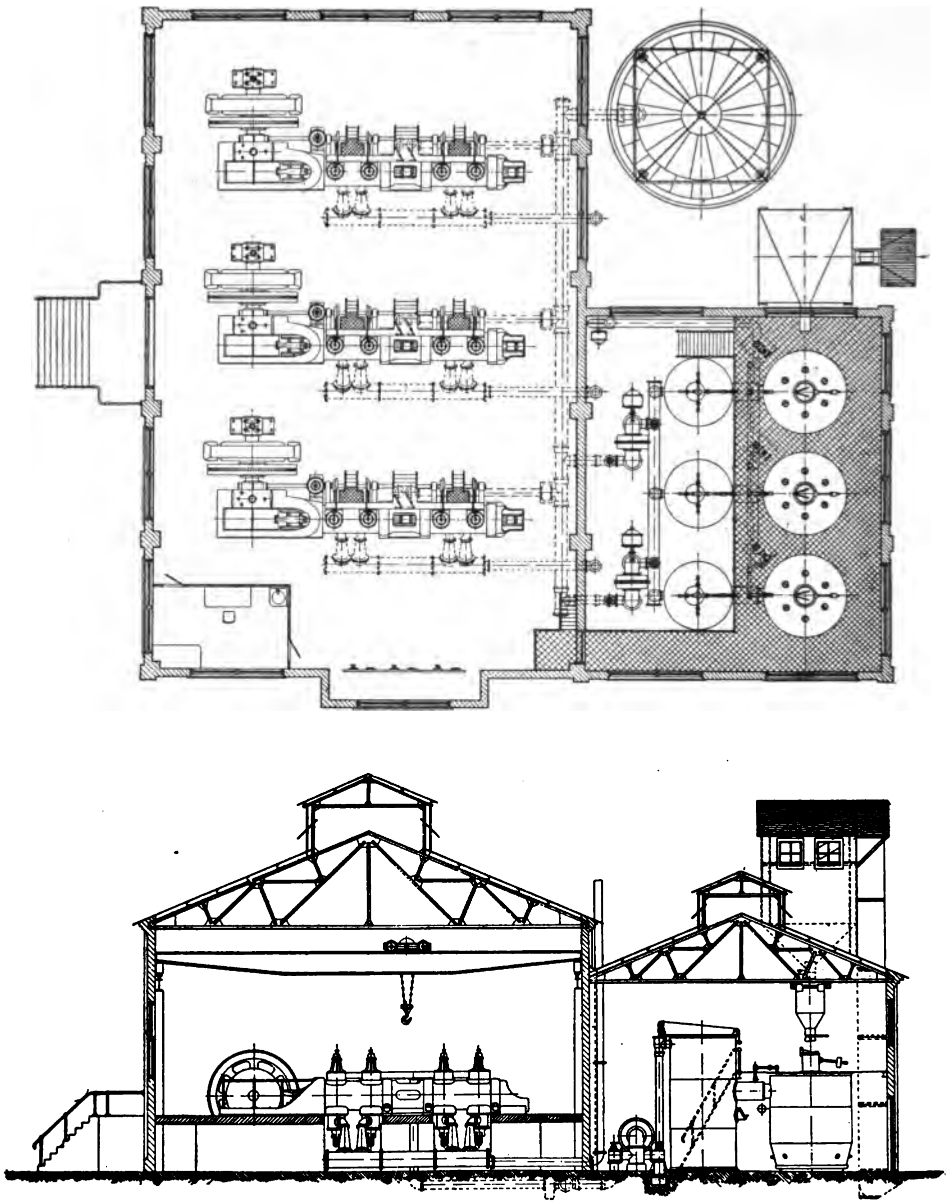


FIG. 106. 1,500 H.P. (WOOD) PRESSURE PRODUCER PLANT FOR BITUMINOUS COAL.

deposited in a centrally located ash bin of sufficient capacity to contain a car load of ashes.

A modification of this plant, where the depth of the coal pit could

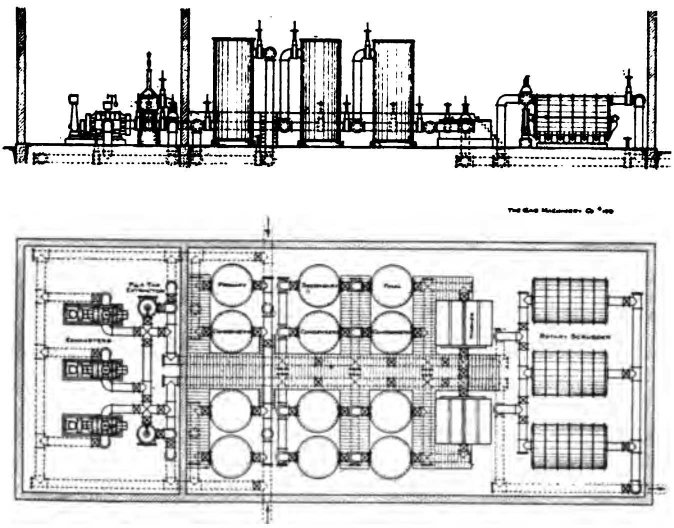


FIG. 107. COAL GAS APPARATUS.

not be as great as that shown in the cut, would be to carry the coal by means of a conveyor from the crusher to a shallow pit, and from this pit it could be handled by an automatic bucket operated from the travelling crane.

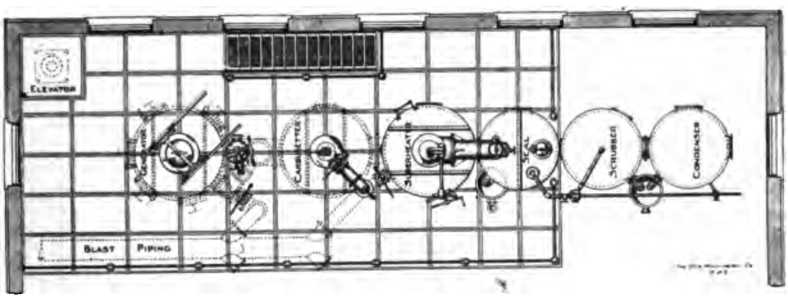


FIG. 108. PLAN OF DOUBLE SUPERHEATED WATERGAS APPARATUS.

With this arrangement a slight addition to the height of the building would be required.

Fig. 104 shows the simplest form of gas producer plant (and the one which may be installed at least first cost). Especially suited

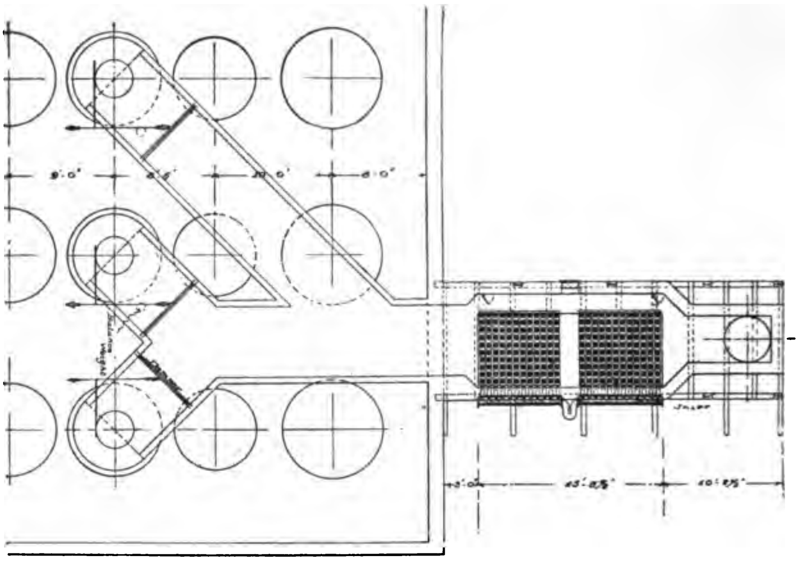


FIG. 109. PLAN OF NEW HAVEN GAS WORKS WITH GREEN FUEL ECONOMIZER.

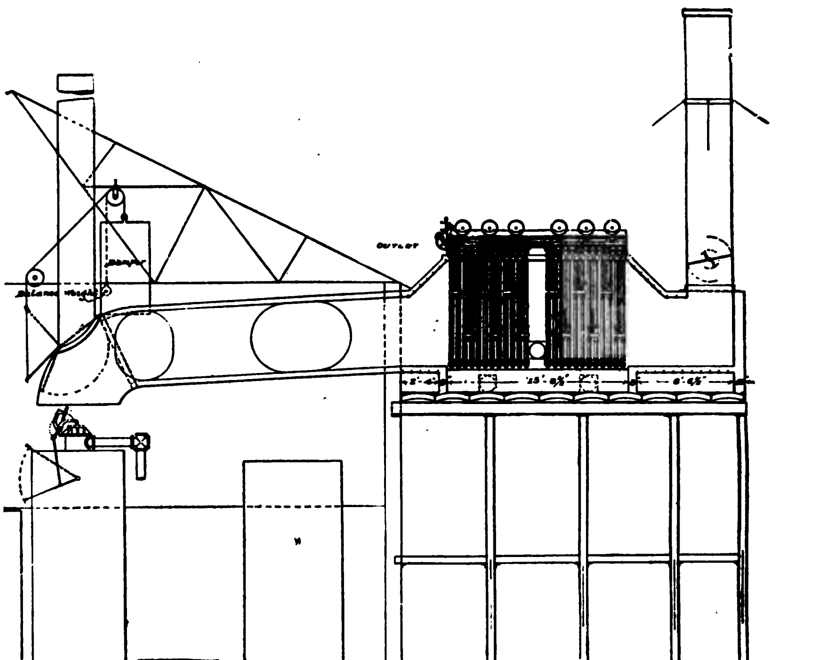


FIG. 110. CROSS SECTIONAL ELEVATION OF NEW HAVEN INSTALLATION.

for plants of one or two small producers or for temporary plants; has also been adopted for larger plants of hand poked producers. The coal is handled entirely by hand, both from the cars to the charging platform and from the platform to the producer.

Fig. 105 shows a desirable installation for a side hill, the coal being dumped direct from the cars to a storage pile below and handled from this pile to the producers by hand. A good arrangement for handling the ashes, if the profile of the property is such that it can be installed, would be to depress a track on the left hand side of the producer for ash cars, so that the ashes could be handled direct to the cars.

The layout of a 1,500-H.P. producer plant for bituminous coal is shown in Fig. 106.

A coal gas plant is shown in Fig. 107, a water gas plant in Fig. 108 and the application of economizers in water gas plants in Figs. 109 and 110. This installation serves for recovering the waste heat from the stack-valve gases.

CHAPTER XIV.

LAYOUT, DESIGN AND CONSTRUCTION OF WATER PURIFYING PLANTS.

Purification by Ozone.—Ozone, as is well known, is best prepared by the silent discharge of the high-tension electricity through perfectly dry air. There are many devices for ozonizing air, most of them being adaptations of the Siemens ozonizer familiar to all students of physics.

The air drawn in the ozonizer is dried by contact with a hygroscopic substance, as $CaCl_2$ or preferably by refrigeration in a chamber cooled as in the freezing machines.

Output of Ozone.—The voltage required to operate this instrument, as installed in Wiesbaden, Germany, is about 80,000 and the generator absorbs 1 horsepower. The amount of ozone produced varies from 13.5 to 27 grammes per hour, the rate of production depending on the dryness of the air which enters the apparatus. This quantity of ozone will purify from 2,200 to 4,400 gallons. Nine ozonizers are in operation, so that a large volume of water is being constantly dealt with. The water supply at Paderborn is also purified by ozone and 12,000 to 16,000 gallons per hour are passed

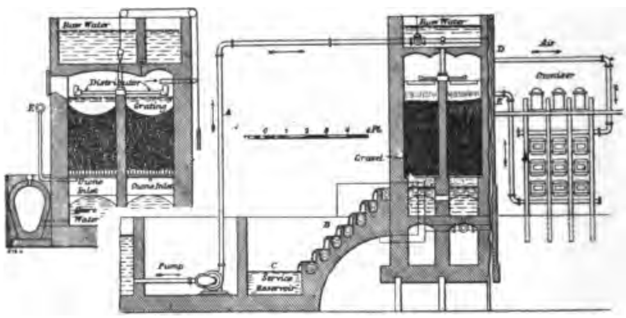


FIG. 111. OZONE PURIFICATION PLANT. (SIEMENS-HALSKE.)

through. The ozone is applied to the water as it descends through gravel beds, the current of ozonized air being forced up from below, as indicated in Fig. 111. The raw water, previously "roughly" filtered, is carried by the pipe A to the top of the sterilizing towers,

and after issuing from these it falls by cascades *B* to the service reservoir *C*. Air is forced into the ozonizer by way of the tube *D*, and leaves with its charge of ozone by *E*. It is made to enter the towers from below and meets the downflow of water through the gravel.

Ginnikin Ozone System (Fig. 112).—More recently an ozonizing installation has been set up at Ginnikin in Holland for the purpose of purifying the water drawn from the river Mark. Normally this stream is discolored, and the number of germs per cubic centimeter is generally about 6,000. Its course lies through fields which are frequently manured from the farm yard. The water from the intake is first passed through filters. Lift-pumps raise the filtered water to a tank placed at the top of the sterilizing tower. This tank has a capacity of 45,000 gals. and ordinarily the pump delivers 4,500 gallons per hour.

The whole purifying outfit is housed in the tower. Electricity is obtained from a local installation, and the 100 volt current is transformed to operate at a pressure of 65,000 volts.

Ozonizers.—The ozonizers are of the Schneller pattern and do not differ in principle from those already described. The outer electrode is hemi-cylindrical in shape, and is kept cool by water circulating in a cast-iron jacket. The inner electrode is the insulated one, and it is of the same form as the outer one, but of less radius.

Sterilizers.—Charged with its load of the purifying gas, the air is forced into the sterilizers, where it encounters the descending stream of water. The sterilizers are cylindrical tubes in short sections. The inner surface is enamelled to protect the metal from oxidation. At each junction of the sections there is a celluloid sieve, resting upon a metallic grid at right angles to the axis of the cylinder.

Ozonized air enters from below and rises with much agitation through the down-coming water, and forms a cushion under each sieve, so that the fine jets of liquid are thoroughly exposed to the action of the ozone. There is indeed an adequate scrubbing of the water at each sieve, air struggling to pass up, and the fluid to gravitate downwards. The water is made to pass through two cylinders in succession, and it issues in a limpid stream, to all extents and purposes sterilized. For out of many samples tested, one half showed no growth from one cubic centimeter after three days, and 20 per cent. no sign of life after six days. Of the remaining 80

per cent. the most developed only one or two colonies of harmless bacteria, and in no case did the number exceed a dozen. Oxidizable organic matter was diminished by about one-half.

The cost of working at Ginnikin is about $9.50 per million gallons.

Relative Advantages.—Costly as this process of purification may be, it is probably one which is well worth the sacrifice of a little money when it furnishes unexceptionable drinking water from a source like the river Mark, whose waters have been justly described as discolored and execrable from a hygienic point of view. The experience at many stations with ozone purifiers indicates that a fair proportion of the ozone goes to waste. Different waters, of course, make different demands on the purifying agent, and it is recommended that tests be made to determine the minimum quantity of ozone that can with safety be applied. Not only would this be in the interests of economy, but it would prevent traces of the ozone being carried to the consumer.

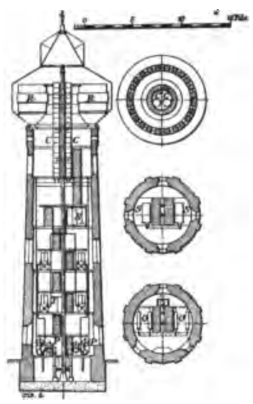


FIG. 112. STERILIZING TOWER AT GINNEKIN.

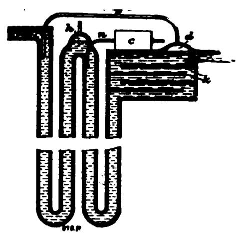


FIG. 113. OZONIZING APPARATUS. (HOWARD-BRIDGE.)

Howard Bridge System (Fig. 113).—The Howard Bridge apparatus effects this useful purpose, and considering that it takes one centime to produce a gramme of ozone, there is good reason to be as sparing as possible with this, the most expensive of all purifying agents in ordinary use.

The Howard Bridge System has the further advantage over installations which use an air-compressor to force the ozone into the sterilizers, that it dispenses with that portion of the apparatus and causes the flow of the water to suck in the ozone. Ozone, as is well

known, acts detrimentally upon lubricants, so that the piston of the compressor has to fit very closely in order that oil may be dispensed with. Suction performs the whole duty of applying the ozone to the water in the Howard Bridge plant, and it is claimed that by it the purification of water can be accomplished more cheaply than by slow sand filtration.[1] Whether that be so or not is a point that still awaits more complete proof. If it, indeed, be true, it is a "consummation greatly to be desired."

De Fries System.—In the De Fries system of ozone purification, which has been tested on a large scale the arrangements are somewhat similar to those at Ginikin. The sterilizers are vertical, inwardly enamelled iron cylinders, divided into many sections by celluloid sieves. The water and ozonized air enter together at the base and the outflow is at the top. The plant can treat 6,000,000 gallons per day at a little more than $4.00 per million gallons. This estimate includes outlay on capital account. This is considerably lower than the cost at the German towns already referred to, where the corresponding outlay to cover all expenditure runs to a figure twice as large.

Vosmaer Ozonizing System (Fig. 114).—The Vosmaer is a spe-

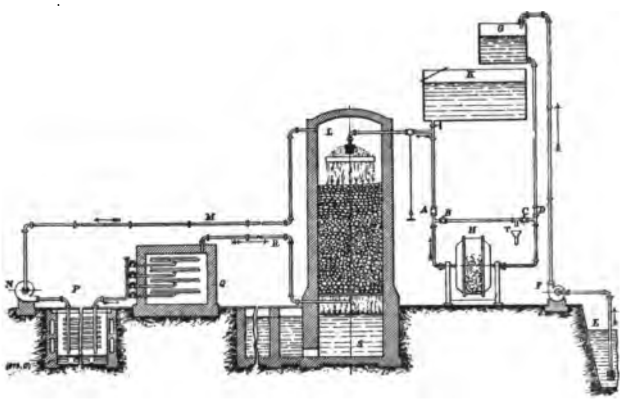


FIG. 114. OZONIZING PLANT. (VOSMAER.) GENERAL VIEW.

cial device for overcoming some difficulties in insulation, and in the establishment of a purely silent discharge. Sparkling leads to the formation of oxides of nitrogen, which would be harmful both to the water and to the apparatus. Vosmaer forms his ozonizer of a series of parallel tubes, each of which contains as electrodes, at

[1] *Journal of the Franklin Institute,* May, 1907.

opposite sides of the inner circumference, two strips of metal, supported upon porcelain insulators. These strips of metal have saw edges pointing inwards and the air sent through the tubes is subjected to the silent discharge from these saw edges of the strips which are maintained at a very high potential difference. A diagrammatic view of the system is shown in Fig. 115 and a battery of the ozonizing tubes in Fig. 116.

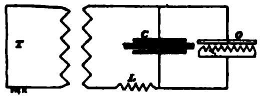


FIG. 115. OZONIZING SYSTEM. DIAGRAMMATIC VIEW.

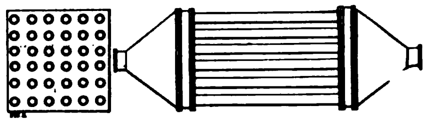


FIG. 116. BATTERY OF OZONIZERS.

Concentration of the Ozone.—It has been observed that satisfactory results have been obtained with widely differing "concentrations" (grammes per cubic meter of air) of ozone, and for each installation there should be determined the most economical value of the concentration. This will be a "constant" of the plant when the data are known. For field filters it is considered best to have a large content of ozone per cubic meter—say, 3 grammes. This means that the air must be drawn along more slowly or the current increased. More ozone, on the whole, is produced if the air current is rapid, but the concentration is lower. This is to say the same horse-power might produce a sum total of, say, 48 grammes, of ozone with a concentration of 0.8 while with a concentration of 3.5 it could only generate 28 grammes in the same time. Experiment will determine the best conditions of working.

Ferrochlore Process of Purification.—When a mixture of chloride of iron and bleaching lime is added to water holding carbonic acid or carbonates in solution, a precipitation takes place, and at the same time a coagulant is formed which carries down the suspended matters. Free chlorine acts as a bactericide. After application of these chemicals, the water being led to filter-beds is easily freed from suspended material owing to the presence of the coagulant. Residual chlorine is eliminated in settling tanks. The amount of chemicals added to the raw water is small, viz., of chloride of iron 8 parts per million, and of chloride of lime 0.5 part.

Precipitant.—Oxide of iron is the coagulant, and if care is exercised in regulating the dose of the chemicals, the filtrate will con-

tain no trace of it. Chlorine is not so easily got rid of, for it is soluble in water to a very considerable extent, and its elimination ultimately rests upon the formation of chlorides. There is an experimental plant on this system at the Paris Water Works capable of treating 1,000 gallons per hour. The results are stated to be very satisfactory, but the cost is relatively high.

Of all precipitants, the cheapest is iron, suitably brought into contact with the water in a metallic state. In the presence of air and salts of lime metallic iron rapidly forms a proto-salt, which first dissolves in the water, and then becoming oxidized by further actioning developes the coagulant which carries down organic matter and fine silt. This is the Anderson Process, and the most important installation is that of the Compagnie Generale des Eaux at Paris.

Anderson Cylinder; Its Construction.—A cylinder is made to rotate by gearing seen at the righthand side of Fig. 117, and the

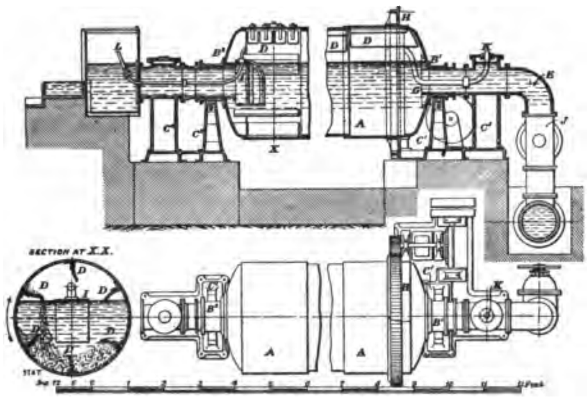


FIG. 117. ROTATING CYLINDER CONTAINING FRAGMENTS OF IRON. (ANDERSON.)

bearings are at B_1, B_2. The inlet and outlet pipes are directed along the axis, and are connected to the cylinder by water-tight collar-joints, which permit of the cylinder rotating. The cylinder itself is built of iron plate and within are many laminar projections which serve to raise up the fragments of iron, and allow them to fall into the water from above so that a quick oxidation results. The rotation is slow, one turn taking from two to three minutes. Air is forced into the space above the water by way of a curved tube, seen at *K*, and the direction of the air current follows that of the water. The outlet is at *L*.

The flow of the water is so regulated that about 3½ minutes

are required to traverse the cylinder, and in that time some 3 grammes of iron per cubic meter finds its way into solution. Small as the quantity is, it serves to coagulate the silt and organic matters suspended in the water. It is averred that there is a diminutive of dissolved organic matter from the moment the water escapes from the cylinder. Further, it is held that any colloidal alumina in the raw water is coagulated by the salts of iron when these pass into the ferric state. On leaving the rotators the water undergoes a preliminary treatment in precipitating basins and decanting compartments, and finally reaches a finishing filter, where the residual iron oxide helps to form a "felting" which intercepts bacteria and sedi-

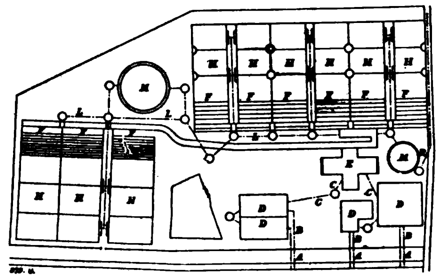


FIG. 117*A*. PLAN OF PURIFICATION WORKS AT CHOISY-LE-ROI. (ANDERSON.)

ment. The plan of a plant arranged on this system is shown in Fig. 117*A*.

The speed of filtration is greater than in British slow sand filters and averages 8 ins. per hour. Nevertheless, the purification effected is superior to that of the average sand filter, for the action of the iron salts is in many ways a valuable supplement to the ordinary process; 99.8 per cent. of the bacteria are removed from the Seine waters, and though from one to two hundred germs per cubic centimeter are still left, they do not seem to be of a harmful kind, for the district supplied by this installation is fairly free from enteric and similar epidemics.

Cost.—The cost of the whole purification process including interest on capital, works out at $5.00 per million gallons.

Retrospective.—The main question at issue would appear to be whether the sand filter is to be displaced by mechanical substitutes in future water undertakings. The latter have many advantages, and are on the whole less likely to permit the escape of unsound water. The Puech system indicates simplification of the method of

working which will possibly be received with increasing favour, especially if the experiments being conducted on the continent are brought to a successful issue.

The question of mechanical sand washing is attracting much attention at present, but taking a broad view of the facts which have come to light in connection with the true action of the filtering skin, it would seem to be a debatable point whether a thorough cleansing of the sand forming the top half inch of the bed is, after all, so very desirable. Clean sand acts as a strainer merely, and has no decided power of trapping bacteria, until it has become coated again with viscous matter, silt, desmids, algæ, *i. e.*, with the very matters that have been so carefully washed away. No one has as yet attempted to show that the fresh coating is in any way more "refined" or purer than the old one. Is it not possible that there is a happy medium in the process of sand-washing and that in clearing a filter that has become clogged, it may be sufficient to break up the growths of algæ and wash off part of the dirt? If there be reason in this view of the case, the problem of sand-washing in open and sand filters would be simplified. Raking of the top layer followed by a back current of filtered water would do all that is necessary. Much time might be saved by sparing a portion of the viscous coating of the particles, for the filtering skin would be able to reëstablish itself more quickly.

Be it remembered that it is not clean sand but dirty sand that filters in the true sense of the word. Hence, those who insist upon thoroughly washed sand, and also those who put much faith in particular qualities of sand from special localities, have probably overlooked the essential point.

Water Hardening and Water Softening.—When the supply of water is abnormally hard or unusualy soft, means have to be adopted to remedy these drawbacks, and there is as a rule but little difficulty in doing so. For the water engineer the point of interest is how to introduce the chemicals in a regulated automatic way, so that no recurring expenditure beyond the cost of the materials may have to be reckoned with. At various places there are installations for effecting this object, and that at Bradford, England, is worthy of attention. The engineer should also be careful that the lime applied for softening is prepared from the purest quality of chalk that is available, free from alumina and its compounds. He must also be aware of the proportion of magnesia in solution if it be present, for

the carbonate of magnesia reacts more slowly than the carbonate of lime and more readily chokes up the filtering screens.

Distribution.—Hardly less important than the purification of the water at the water works is the distribution of it to the consumers undeteriorated by its journey through the mains and service pipes. Its passage from the reservoir or filter-beds to the consumer's taps brings it into contact with pipes of iron and lead. Both of these metals may, under special circumstances, find their way into the current, and may very seriously impair the purity of the supply.

Growth in Water Mains: Crenothrix.—Among the many lowly forms of life whose myriad forms the water engineer seeks either to exterminate or to impress into service, there is one which finds a harborage and breeding ground in his water mains to the detriment of the carrying capacity of the same, and to the quality of the water contained. This is the animalcule known as "crenothrix," germs of which appear to be widely distributed in soils and streams. It cannot multiply without the presence of iron in the water, and about 0.3 part per million in solution is sufficient for its activity. The cell walls of the plant secrete or separate iron from the water and within these minute tissues it becomes oxidized. The filaments, continuing to grow, form a network of ferruginous material adherent to the walls of the pipe. Under favorable circumstances this growth reduces the carrying capacity of the main as much as 1 per cent. in the year. When, owing to one cause or another, regurgitation occurs in the mains, quantities of the oxide are carried away by "scour" and this gives rise to discoloration of the tap water, and at times to offensive odors. The experience of water managers in America and elsewhere leads to the conclusion that the best method of dealing with crenothrix is to remove the dissolved iron and this can be affected by using a suitable coagulant.

Action of Service Water Upon Lead Pipes.—Although lead is insoluble in distilled water, pure water containing air in solution acts upon the metal and forms on the surface a deposit of $Pb(OH)_2 \cdot 2PbCO_3$. At the same time some part of the lead passes into solution probably in the form of acid carbonate. The presence of alkaline carbonates, or of silicate of lime, arrests the solvent action of the water. In that case, the insoluble hydrocarbonate (whose formula is given above) alone is formed. This deposit is adherent to the surface and tends to prevent further action.

Peaty Water and Soft Water.—Water collected from moorlands

and mossy grounds is usually soft and contaminated with vegetable matter and, in particular, with humic and ulmic acids. Such water has an increased influence upon lead, and is capable of dissolving as much as one to two grains per gallon in twelve hours. Service waters containing 0.01 to 0.03 grain per gallon have not as yet been proved to be detrimental to the health of the community. In general the safeguards that have been adopted against the solution of lead have been the removal of peaty matters by alum or other precipitant, and the hardening of the water by the addition of lime. At Wakefield, England, where much difficulty was experienced in counteracting the solvent of the service water, one grain of chalk per gallon was introduced into the raw water, and two grains of lime to the same volume of the filtrate. The result of this is that the water now dissolves minute quantities of lead, only 0.03 grain per gallon in twelve hours' time. The lime which is applied to the filtered water at Wakefield, is placed, after slaking and riddling, in a hopper with a perforated bottom, and jets of water playing upwards from below wash down the lime to the mixing pan. From that, the water passes on to a series of settling cylinders, entering them from below and over-flowing into a receiving trough connected to the service reservoir. The chalk, which is added before filtration, is washed out of a hopper in the same way. The cost of materials and labor for this particular treatment amounts to about 4s. 6d. per million gallons.

Dr. Houston has experimented with many natural waters, and he finds a distinction must be drawn between "plumbo-solvency" and "erosion." Rain water erodes, but does not dissolve, lead, while moorland waters do both. Many natural waters, more especially hard waters, are in a condition which is protective against a solution of lead.

Reserve of Plumbo-Protective Matter.—Faintly acid moorland waters have but trifling erosive power, but Dr. Houston shows that they are often near the conditions of being able to erode. This is shown very clearly by causing such waters to act for a time on bright lead, and then renewing the metal a few times. The small reserve of plumbo-protective substances which they possess is thus exhausted and a vigorous action follows. This is a new fact in connection with lead contaminations, and the deduction to be made is that corporations using waters of this class would do well to ascer-

tain what reserve of protective substances they can count upon in the supply.

Solution of Lead Traced to Voltaic Action.—The occurrence of a case of leading poisoning at Twyford, Hants, led to the unexpected discovery that a water which is normally without action upon lead may take up quite a dangerous percentage of it, if the pipe happens to be conveying a current of electricity. In the case mentioned the current was traced to a leak in the electric-lighting wire in the house where the patient resided. A current of the same voltage was passed through a lead pipe filled with the house water for a number of hours, and it was proved that lead has passed into a solution to the extent of 0.07 grain per gallon. Ionization is set agoing by a current of sufficiently high voltage, and some part of the metal passes into solution.

Precautions.—It appears, therefore that electric mains should not be placed in the vicinity of the water pipes and that in any case care should be taken to see that the wires are properly insulated. It has always been a common practice to "earth" wires by joining up to the water pipe, but there is obviously a grave danger in this procedure, more especially if the current is of high voltage.

Concluding Remarks.—Water purification is a practical science of recent growth, but it ramifies into so many other branches of technology that workers in several distinct fields are periodically adding new facts to the increasing store of learning in connection therewith. The growth has been rapid, in consequence of the activity of the tributary sciences. The amateur and the man of empirical knowledge have had their day—their successes it may be, their blunders it is certain, but the future is for the technical expert. It is too vital an element in the health of communities, this question of the purity of the water supply, to be put into the hands of those of whom the very best that can be said is that they feel their way. We are less advanced than our continental friends in the study of water purification, because the lessons brought home by the deadly results of contaminated water have neither been so frequent nor so incisive as in countries less abundantly provided with naturally pure water. We have been content to conserve our established processes and to accept results without seeking to probe too deeply into the cause of occasional failures or recurring divergencies. But science is on the march and under her silent footsteps all that is vague and crude and unreasoned will tend in time to disappear. With a more

accurate knowledge of the intricacies of the purification of supply water, we shall be able to attain our ends with economy and, what is still more important, with certainty.

Water Distilling Plant.—The Mirrlees Watson Company, Limited, of Glasgow, has a few years ago completed two exceptionally large water-distilling plants, to the order of the Egyptian government, for erection and service at Suakin, on the Red Sea, where they will supply pure water not only for drinking purposes, but for use in locomotive and other boilers. We believe that these are by far the largest plants for this purpose yet made. Each plant is

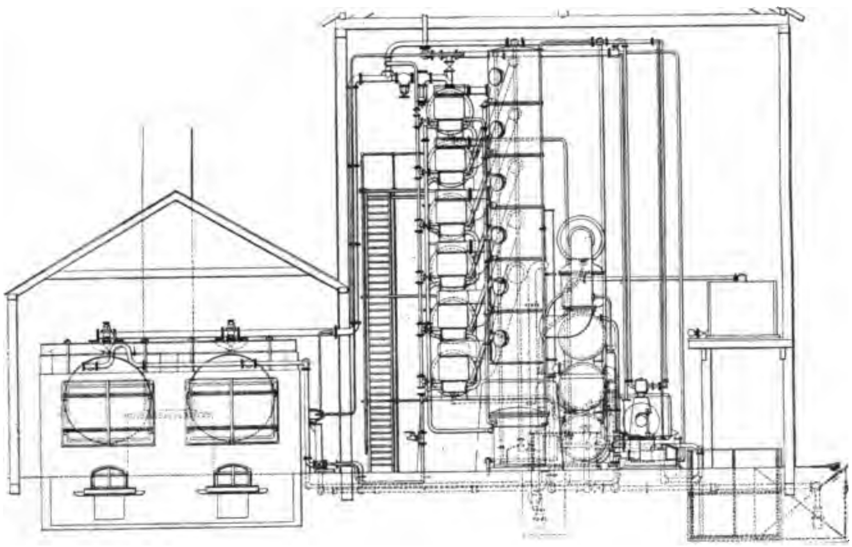


FIG. 118. WATER DISTILLING PLANT FOR SUAKIN. ELEVATION.

designed to produce 350 tons of pure distilled water per day when working at its most economical output. A considerably larger quantity of water can, however, be obtained, but at a slightly reduced efficiency. Speaking generally, it is true that where good water is scarce, so also is fuel, hence it is imperative that apparatus intended for the distillation of water on a large scale should be designed to work at the highest possible economy. That this condition is met in the apparatus before us is evident from the fact that for every net 1 lb. of coal burnt, at least 45 lbs. of water will be evaporated and condensed, in addition to the evaporation of 8 lbs. to 10 lbs. of water in the boiler supplying steam to the plant. In

other words, 45 lbs. of pure distilled water will be produced and rendered available for every 1 lb. of coal burnt. This figure has been exceeded on many tests of even much smaller apparatus turned out by this firm.

Below, in Figs. 118–120, we give drawings and engravings showing the general construction and the method of working this notable distilling plant.

The plant consists of two sextuple-effet distillers, with air and auxiliary pumps, surface condensers, and preliminary heaters. Each apparatus is guaranteed to produce 350 tons, or 78,400 gallons of fresh distilled drinking water per day of twenty-four hours. An

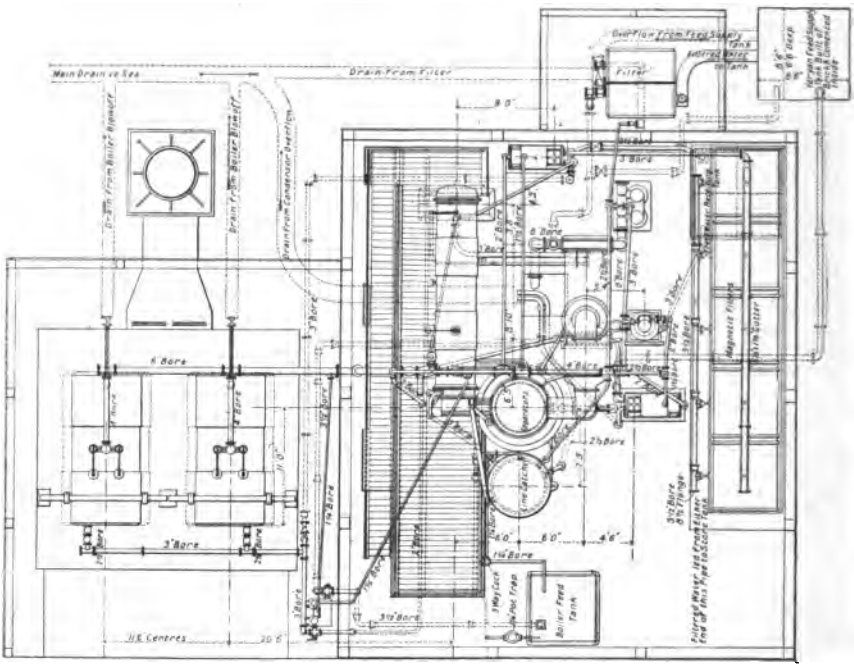


FIG. 119. WATER DISTILLING PLANT FOR SUAKIN. PLAN.

independent boiler plant, salt water mechanical filter, and a set of filters for aerating the distilled water before it gravitates to the storage tanks, are provided for each distiller. The distillers are designed on the Mirrlees Watson Company's well-known Yaryan system of multiple evaporation. The vapor generated in the one effet, on separating from the liquid, passes to the shell containing the circulating tubes of the following effet. The boiling point of the liquid

passing through the tubes at each point being at a lower temperature than that of the vapor in the surrounding shell, the vapor in giving up its latent heat again causes evaporation of the water in the tubes. The working pressures in the apparatus graduate proportionally through the various vessels, from about 40 lbs. pressure per square inch in the first to about 27 ins. vacuum in the last.

The method of working the plant may briefly be described, and in this the drawings with reference letters will assist. The salt water is drawn from the sea by the circulating pump, and is, in its passage through the condenser tubes, slightly raised in temperature. The

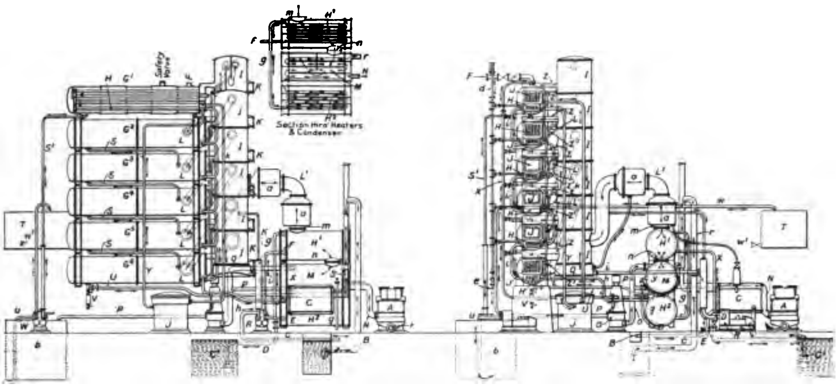


FIG. 120. DIAGRAMMATIC ARRANGEMENT OF SEXTUPLE EFFECT WATER DISTILLER.

overflow from the condenser is arranged so that the feed to the distiller gravitates through the mechanical filter, before entering the distiller supply tank, to eliminate any organic or other matter drawn from the sea. A connection is also provided to allow of the feed passing direct to the tank in the event of the filter requiring cleaning. The salt water is drawn from the supply tank by the distiller feed pump, and discharged through the first and second heaters, which are fitted with brass tubes and tube-plates, as in the case of the condenser. In the first of these heaters the water is again raised in temperature by the heat given off by the vapor from the sixth effet on its passage to condenser, and in the second by exposure to the heat of the distilled water from the sixth shell, which is also drawn to the condenser. The feed then passes to a heating coil arranged at the bottom of the last effet, and from there it rises, through similar coils in the successive vessels, gradually increasing in tempera-

ture, to the top vessel, or first effet, where it is exposed to the heat given off by the steam from the boilers, which is employed at this point. The supply then passes down to a lime-catcher on the floor, heated by a coil supplied direct from the boilers. The rise in temperature at this point causes most of those impurities, which could not be eliminated by the cold salt water filter, and which can be treated without evaporation, to precipitate and deposit; the water being strained through an internal perforated vessel filled with charcoal. The feed-water being now raised to full boiling point passes up into the evaporating coil of the top vessel or first effet, and the process of evaporation commences.

The salt water heated by steam from the boilers in the first effet, together with the vapor, now enter the first separator, which is fitted with baffle-plates to prevent the entrainment of water with the vapor generated. This vapor is drawn to the shell of the second effet, where it is employed in again evaporating the water drawn from the first separator. Copper strainers are fitted in the separators to catch any deposit in the feed before it enters the coil of the second effet. A similar process is gone through in the passage of the feed down through the succeeding effets to the sixth, or last separator, when the vapor is drawn through the first heater to the condenser, and the remaining feed, in the form of concentrated brine, about 25 per cent. of the original volume, is drawn off and discharged by the brine pump.

The steam is supplied from the boilers to the first effet at a reduced pressure, and this supply is augmented by the exhaust steam from the various pumps. The drain water condensed from the steam is returned direct to the boilers from a feed pump. A separate feed pump is also supplied with each set of boilers for feeding from the hot-well or with sea water. The drip or drain from the second effet passes to the third effet, and there gives off some of its remaining heat to assist in the evaporation in the coils of that vessel. A similar process takes place through the remaining effets, and from the last effet the distilled water is drawn through the second heater to the condenser. The fresh distilled water is discharged from the air pump to a tank, and from there pumped up into the set of filters before gravitating to the storage tanks.

The apparatus is fitted throughout with cocks and valves for adjusting the flow of the feed-water through the various vessels, and

can, we understand, easily be adjusted so as to render the working automatic. A staging is supplied for convenient access to all parts, and to allow of cleaning and scaling the tubes in the vessels, which in this case are 3 ft. 9 ins. in diameter, and fitted with solid drawn brass tubes 3 ins. external diameter by 17 ft. 6 ins. long, expanded into brass tube plates.

An efficiency of 48 lbs. distilled water per 1 lb. of coal consumed in the boilers—due allowance being made for ashes—over and above the condensed water from steam returned for feeding boilers, has frequently, so we are informed, been got with similar plants supplied by the firm.

The Mirrlees Watson Company, Limited, it may be added, has already constructed sea water distillers, of the Yaryan type, to the order of the Egyptian and Turkish governments, for the caravan and pilgrim stations of Kossier, Camaran, etc., on the Red Sea. Similar plants have also been supplied to many other parts of the world, including the Island of Perim; Mombassa, for the Uganda Railway; Western Australia, the Argentine Republic, Russia, etc. Three distilling plants for dealing with impure water are at present on order for the Cape of Good Hope government railways. Where the production of salt from sea water is commercially profitable, an arrangement can be added to the distilling plant, for the further concentration and refinement of the brine.

The distiller can be used in connection with refrigerating machines, for the production of pure ice. The firm's Yaryan apparatus is also largely used for the concentration of various products, such as meat extract, gelatin, glue, dyewood extracts, caustic soda, borax, etc., and numbers of such plants are manufactured every year for both home and abroad.

CHAPTER XV.

LAYOUT, DESIGN AND CONSTRUCTION OF DRYING PLANTS.

The conditions for drying different materials in various industries vary widely and require individual attention and designing.

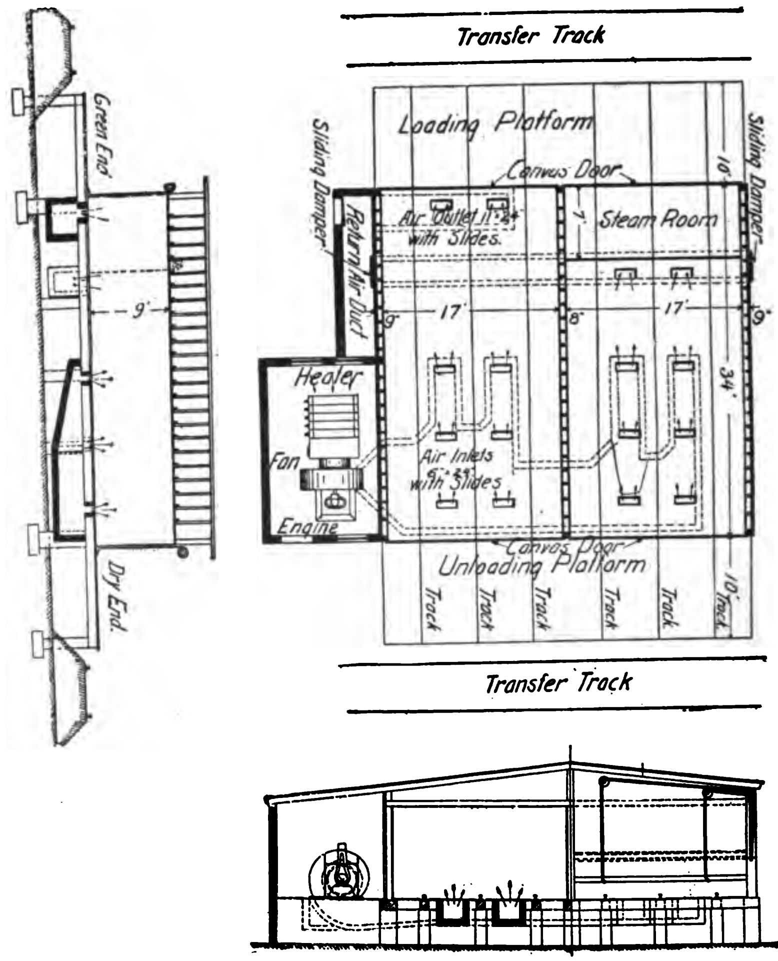


FIG. 121. DRY KILN; INDIRECT SYSTEM WITH EXHAUST STEAM HEATER COILS AND PAN.

Air moving and drying plants differ in their requirements; hardly two are alike. Not only is there the entire range of pressures and

volumes and temperatures, but the fan must often be built to fit a given space, to be driven by a certain type of prime mover, to run at a given speed, etc. The possible combinations of these requirements are almost endless and, while it is true that standard fans may be speeded up or otherwise slightly modified to meet circum-

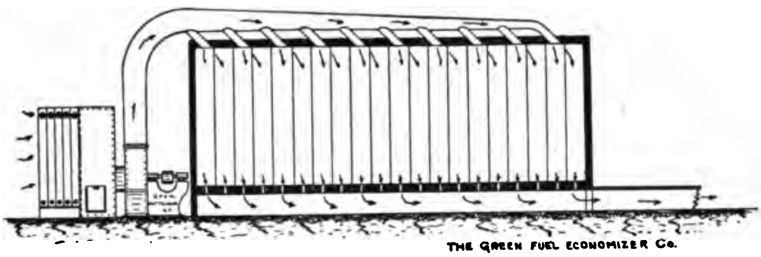


FIG. 122. LAUNDRY DRYER WITH FAN AND STEAM HEATER.

stances, the probability is that they will not be as suitable for the work as would a fan designed for the particular place.

The type of fan to be used in a drying installation will depend largely upon the volumes and pressures required.

It should be borne in mind that the power consumed by a fan

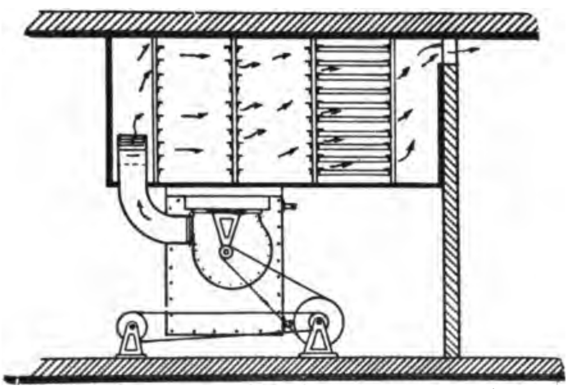


FIG. 123. SMALL DRYER FOR BAKING POWDER.

increases more rapidly than the speed and that a fan too small for its work will eat up its cost every year in the extra power required to drive it. Further, fans run at too high a speed get hot bearings and shake to pieces generally, especially where they are of cheap construction.

In some industries the drying of materials is carried on by drying rolls or tables and the water vapor escapes into the air of the room.

Take, for instance, paper mills and dyeing establishments, where the problem is not only one of moving and heating air, but also of preventing excessive humidity. There is practically only one way

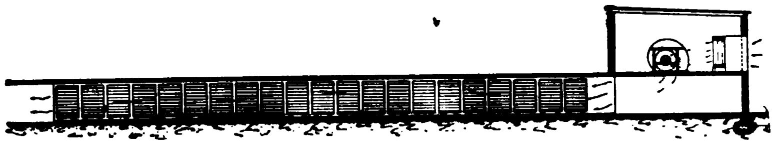


FIG. 124. GLUE DRYER WITH GREEN FAN AND HEATER.

of removing the water evaporated from a paper machine, for instance, and that is by sweeping it out from the machine room with a large volume of air. The principal trouble, however, arises in the Winter by the condensation of vapor upon the roof and skylights, whence it drips upon and ruins the paper. This happens long

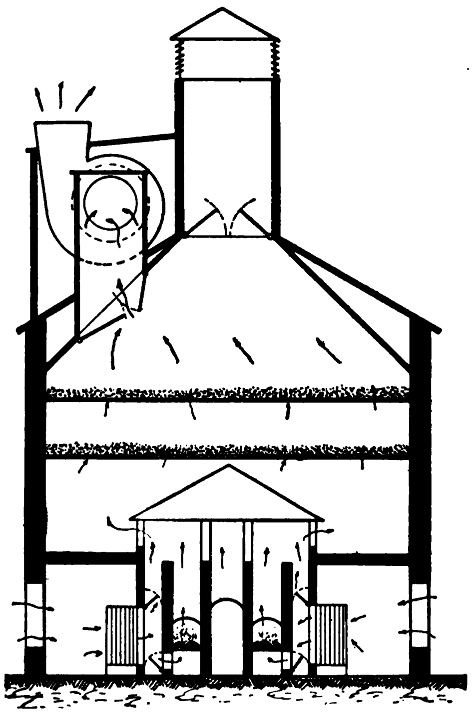


FIG. 125. MALT HOUSE KILN.

before the air of the room reaches saturation, or the "dew point," as it is sometimes called. It can be prevented by a constant supply of warm, dry air from a fan and heater.

Installations are shown in Figs. 121–125.

CHAPTER XVI.

LAYOUT, DESIGN AND CONSTRUCTION OF ACID PLANTS.

Roasting plants for the production of sulphurous acid gas from pyrites by means of McDougall furnaces are herewith illustrated. Fig. 126 is typical of practice where the contour of the ground will permit of ore cars being run directly over the top of the furnace for unloading into the feed hoppers. Fig. 127 shows a plant, the plan of which is often followed where it is impractical or inadvisable to extend tracks directly over the furnace. In this plant it would have required an expensive trestle to permit of the ore cars being directly hauled to the charge floor, as the ground was uniformly level. For this reason, a bucket elevator, together with a belt conveyor extending the full length of the building, was adopted.

The general arrangement of a sulphuric acid plant, chamber process is shown in Fig. 128. The SO_2 produced in *S* travels through *r* to the denitrating tower *G*, through which the nitrose is flowing. The acid is discharged at the bottom of *G*, one portion of same being lifted to the top of the Gay Lussac *L*. The gases and the vapor (from pipe *v*) travel through *A, b, B, C* and *L* and escape through *n*. The acid which leaves *L* at the bottom passes through *o* to the Montejus *D*, by means of which it is lifted to the top of the Glover *G*.

A denitrating tower is illustrated in Fig. 129.

The Evers system of denitration is shown in Fig. 130.

The object of this apparatus is to regenerate, by employing certain special apparatus, H_2SO_4 and HNO_3, which were heretofore regenerated in an inferior quality by the denitration of waste acid, in such way that both, the H_2SO_4 and HNO_3, can again be used or, if no concentration apparatus is on hand, to dispose of these acids to factories at prices, which are usually paid for commercial products and not for waste acids.

The apparatus is arranged to produce, without previous heating, by direct denitration of the waste acid, immaterial whether the same contains organic matters or traces of nitrous substances, a white

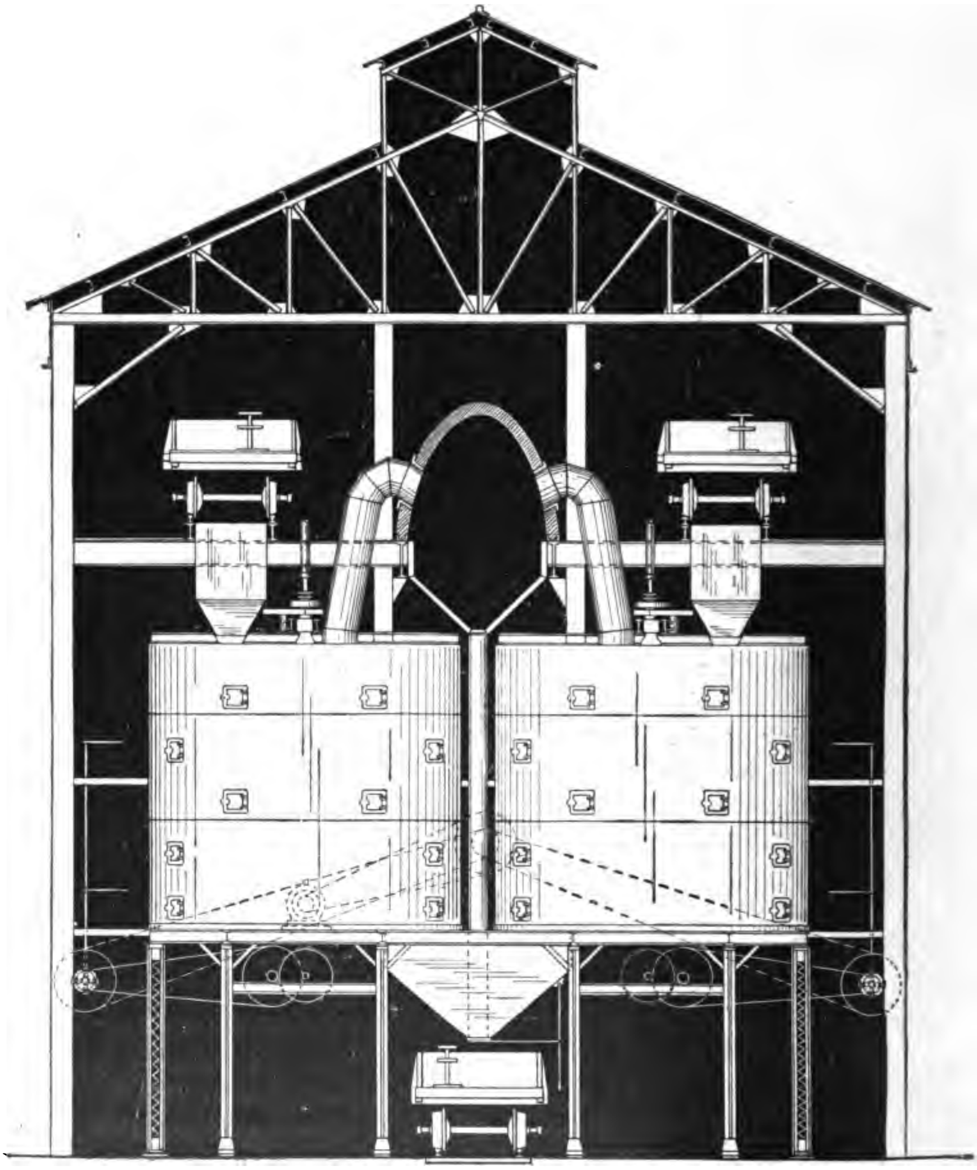


FIG. 126. McDOUGALL FURNACE ROASTING PLANT.

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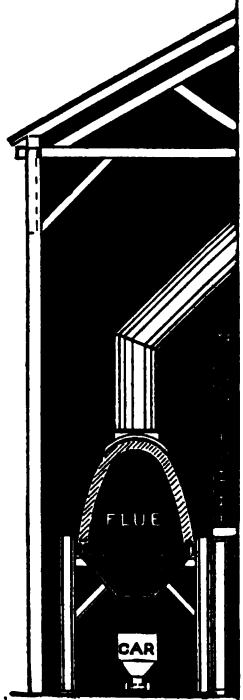

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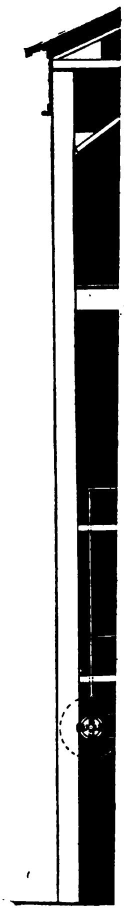


H_2SO_4 of 60° Bé and HNO_3 either white of 34–36° Bé or yellowish of 36–42° Bé.

This result is obtained by introducing highly heated gases in the

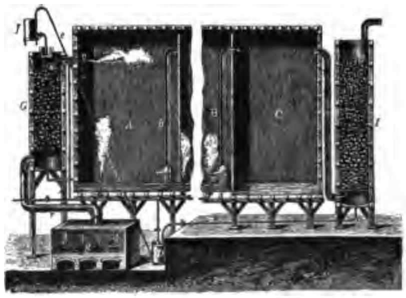


FIG. 128. ARRANGEMENT OF SULPHURIC ACID PLANT, CHAMBER PROCESS.

bottom cylinder and other places of the denitrating tower and by using the above mentioned special apparatus, which for the towers consists of arched, perforated plates and of revolving bodies, and for the condensation pipelines of so called bunches of pipes (12 stoneware pipes, about 45 cm. long, combined to one body).

The revolving bodies, which rest on the arched plates, consist of two hollow cones, placed one over the other, the outer cone revolving by means of arms, similar to a Segner wheel, in such way that openings which in both cones correspond, permit a free passage to the gases when the openings cover each other or cause an oscillating motion of the gases when the openings are closed.

Should, for some reason or other, the cones cease to revolve, their presence will still further the chemical process as the outer cone is also provided with a number of rims, holding

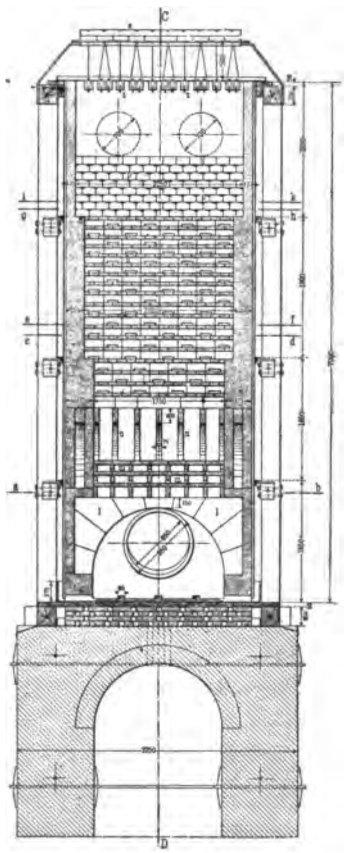


FIG. 129. DENITRATING TOWER.

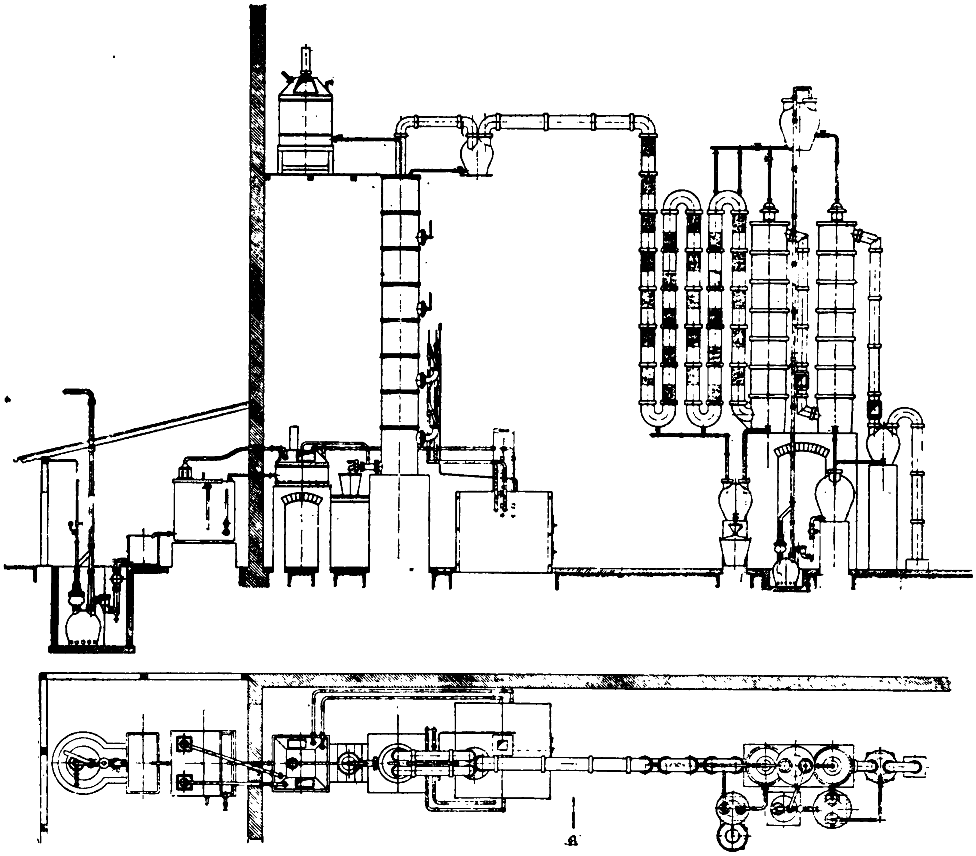


FIG. 130. DENITRATING PLANT, EVERS SYSTEM.

the distributing liquid, through the overflow of which the gases are forced to pass and thus to come in most intimate contact with the liquid. The rest of the tower is filled with a packing which guarantees a most protracted passage of the gases as well as of the acid.

By using heated air the oxidation of the organic matters, contained in the acid, is a radical one, their decomposition is complete and the result is white H_2SO_4. The heat of the escaping acid of 60° Bé serves at the same time to raise the temperature of the entering air.

The above described bunches of pipes are in condensation pipelines. Tourills are not used, which fact is important, considering the expenses for freight and duty when plants are shipped for export. These bunches of pipes are constructed in such way that

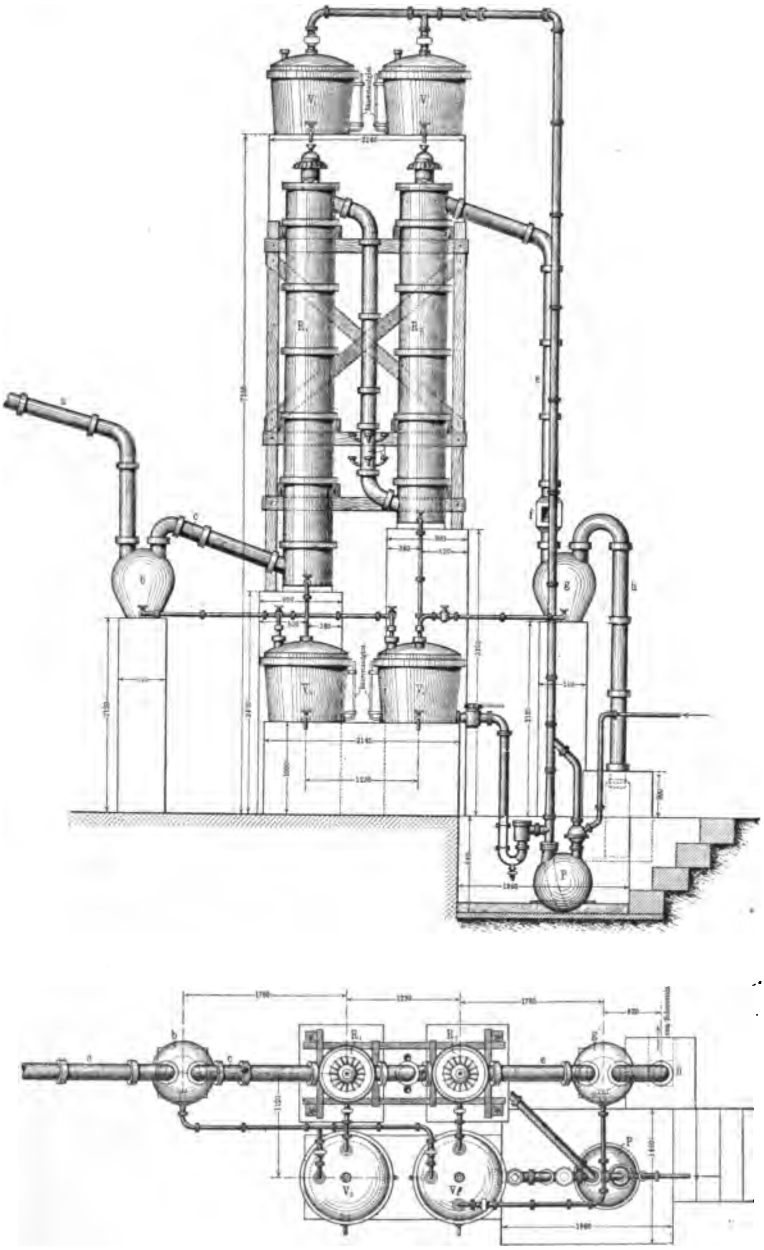


FIG. 131. REGENERATING PLANT.

they cause a continuous mixing of the gases by throwing them in short distances from the center against the walls of the pipeline and driving the gases from there to the center. In this way the gases are continually mixed, a process so exceedingly favorable for the oxidation of nitrous gases and a reason, why the apparatus is now commonly used for regenerating purposes.

From the last two pipelines therefore HNO_3 of 36° Bé to 38°, sometimes 40° Bé runs off while the acid from the first pipeline

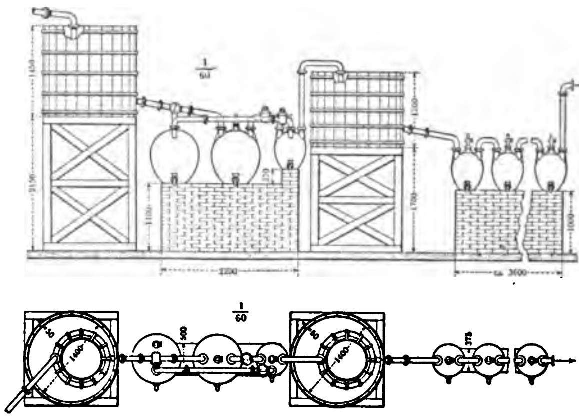


FIG. 132. NITRIC ACID PLANT, VALENTINER SYSTEM.

being united with that running off from the last towers, is used as distributing liquid for the first tower.

The working of the apparatus does not require any special attention, as the injectors on the denitrating tower work automatically and a likewise automatic Montejus lifts the acid, which runs off from the tower, until the acid, in a concentrated state, leaves the last pipeline and the first tower.

The apparatus is now improved to such an extent that with one pipeline only, the highest yield is obtained. The apparatus uses in 12 hours from 8,000 to 10,000 kilos normal waste acid of 70 per cent. H_2SO_4, 20 per cent. H_2O and 10 per cent. HNO_3 and regenerates the H_2SO_4 to a white acid and the HNO_3 at a loss of only about 0.1 per cent.

A complete denitrating apparatus consists of: One iron denitrating tower, lined with acid-proof bricks, injectors, packing, the revolving bodies, the battery of bunches of pipes, the absorption tower, one automatic Montejus; where no compressed air arrangement exists, the acid can be raised by using a pump.

A regenerating plant is shown in Fig. 131.

A nitric acid plant, system Valentiner is illustrated in Fig. 132.

The operation of Guttmann's condensing battery for nitric acid

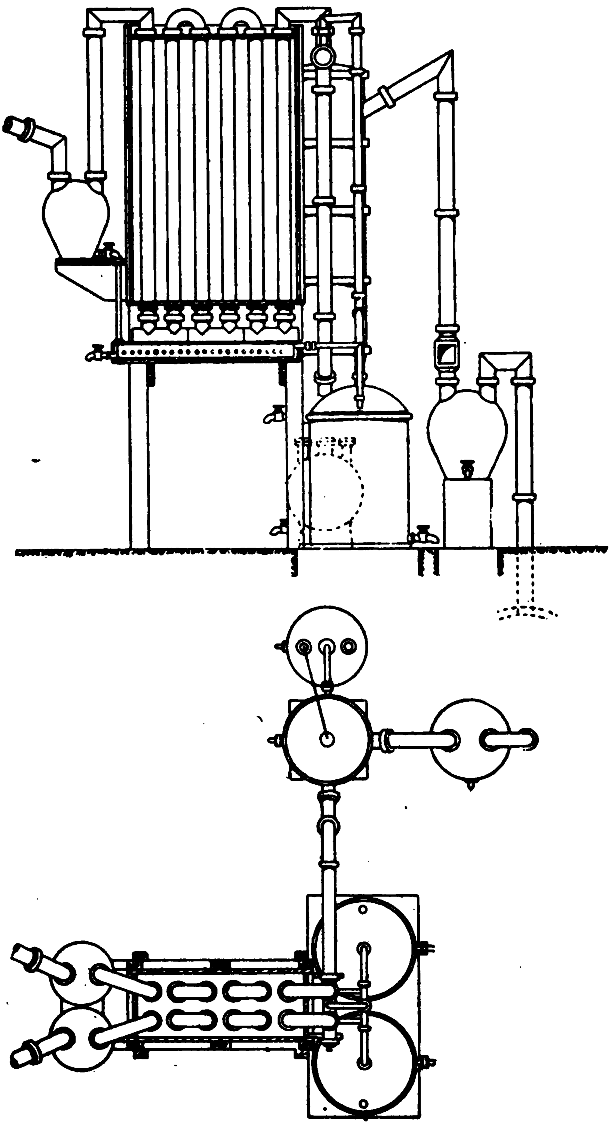


FIG. 133. CONDENSING BATTERY FOR NITRIC ACID, GUTTMANN SYSTEM.

(Fig. 133) is as follows: The gases on issuing from the still are rapidly condensed in a receiver and six long water-cooled stoneware

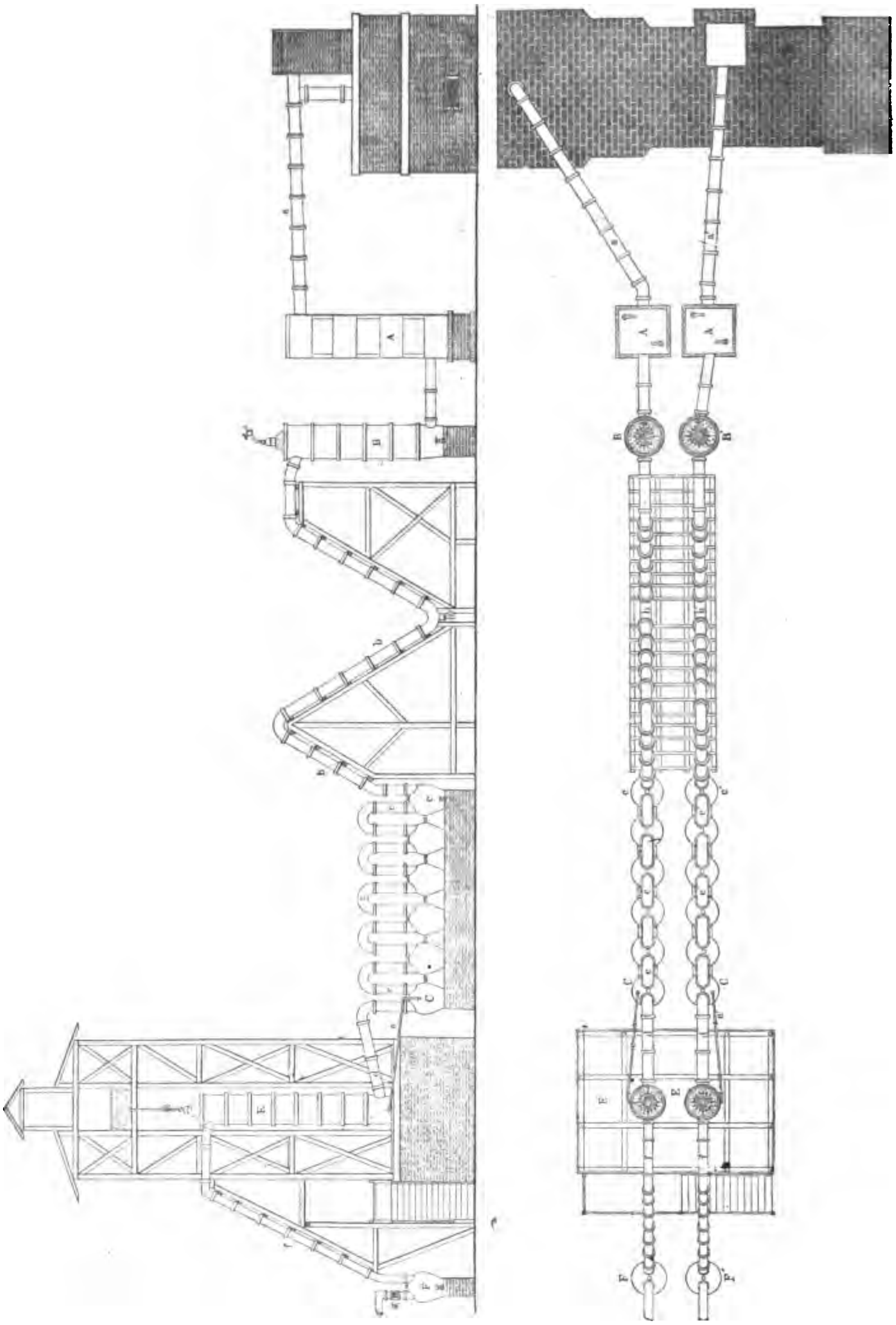


FIG. 134. HYDROCHLORIC ACID PLANT.

pipes at such a temperature that a minimum amount of the water contained in the gases is separated while the nitrous acid and chlorine remain in the gaseous state. These gases pass through the battery to the absorption tower, the temperature in the latter being so regulated that the chlorine and part of the water are driven off. The nitrous acid, however, is almost completely oxidized to nitric

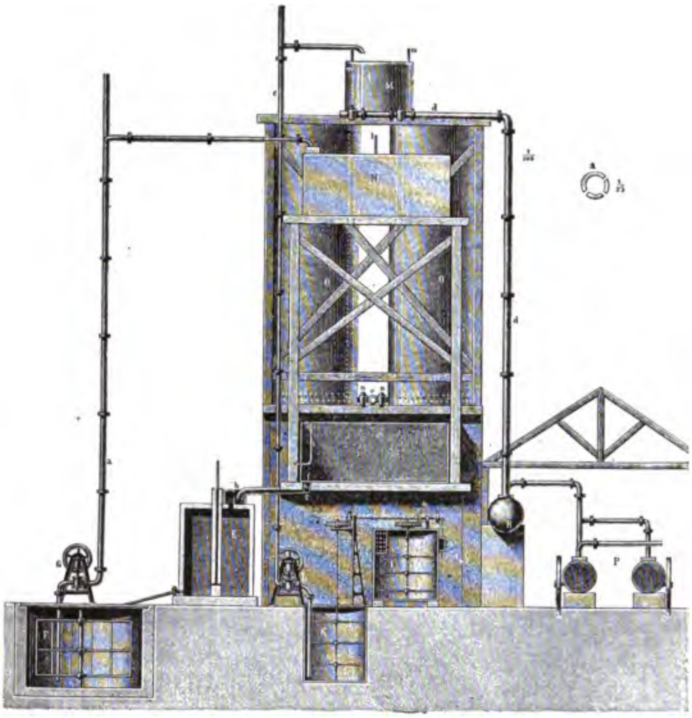


FIG. 135. WELDON'S APPARATUS FOR REGENERATING PEROXIDE OF MANGANESE.

acid in its passage through the battery to the tower, this effect being obtained by simultaneous injection of air.

In order to obtain these results the nitric acid, after condensation has taken place, has to be rapidly removed from contact with the uncondensed gases. For this purpose drain pipes are attached to the lower ends of the connecting elements, leaving a free passage for the gases. The drain pipes dip into the acid, which collects in a tubular cooling channel before running into the storage vessel; any gases evolved in this being conducted to the tower.

If it be desired to thoroughly "bleach" the acid, a little com-

pressed air, which has been heated by an iron coil placed in the flue of the still, is blown into the storage vessel. When bleaching in this way the cooling water in the cooling channel has to be so regulated so as to be at a temperature of at least 50° C. on leaving the cooler.

A battery of six pipes can readily condense the distillate obtained from a charge of 2,000 lbs. The whole of the acid produced is of one strength only, so that no further blending is necessary. The acid when collected in the storage vessel is at such a temperature as not to irritate the workmen while drawing it off.

Guttmann's condensing battery may be used for the manufacture

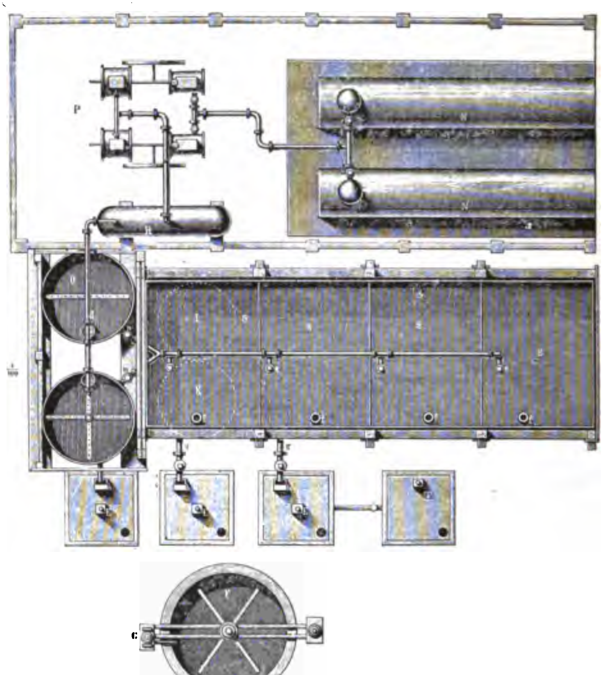


FIG. 136. WELDON'S APPARATUS FOR REGENERATING PEROXIDE OF MANGANESE.

of nitric acid of any desired strength by charging the tower acid again into the still and recovering it as strong acid at the next distillation.

The acid produced with Guttmann's battery is nearly chemically pure; it is free from chlorine and sulphuric acid, and only contains small quantities of nitrous acid. Nitric acid of 96½ per cent. (specific gravity 1.507 = 48.4° Beaume) contains about 1 per cent.

of HNO_2; acid of 1.420 specific gravity (42.7° Beaume) only contains traces.

The usual charge for a still is 2,000 lbs. of 96 per cent. nitre. For the production of highest-grade nitric acid, 2,420 lbs. of sul-

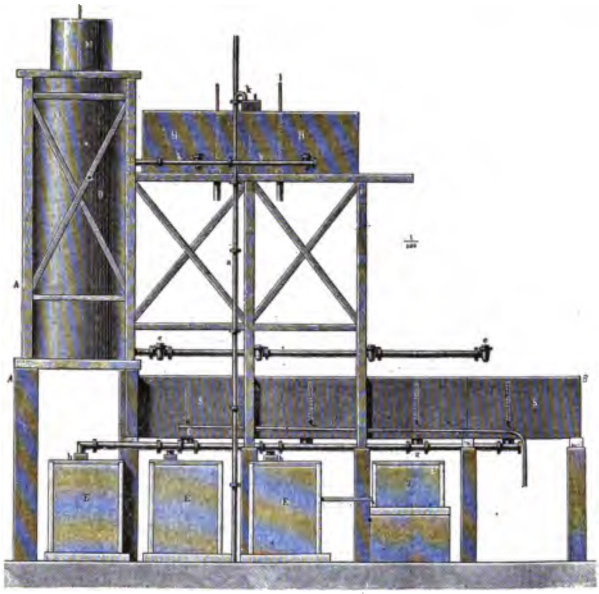


FIG. 137. WELDON'S APPARATUS FOR REGENERATING PEROXIDE OF MANGANESE.

phuric acid containing 94½ per cent. monohydrate (1.838 specific gravity) are required; for the production of nitric acid of 1.420 specific gravity (42.7° Beaume), 2,536 lbs. of sulphuric acid of 79.36 per cent., or 1.725 specific gravity, are required.

Waste acid, such as that from the manufacture of gun cotton, may be used, and the nitric acid contained therein recovered as strong acid. The yield is in every case between 99 and 99½ per cent. of that theoretically possible without the production of any weak acid of inferior value.

The coal consumption is 250 lbs. per charge of 2,000 lbs. of nitre. The distillation takes about 10 to 11 hours; charging, emptying and drawing off require another two hours. The quantity of compressed air required for bleaching is about 100 cu. ft. at 45-lb. pressure per charge, and the consumption of water is 450 to 650 gals. Three men can easily work eight stills, two men four stills, while one man and an occasional helper are required for two stills.

With Guttmann's battery one can, of course, distil weak nitric acid by mixing it with sulphuric acid of 1.840 specific gravity and distilling in suitable stills. A uniform acid containing 96 per cent. nitric acid can hardly be obtained when distilling in cylinders as too much cooling takes place at the ends, and stills are required which are surrounded on all sides by the flue gases. A good absorption tower, like a Guttmann ball tower, is another condition; one of 2 ft. 4 ins. diameter is sufficient for four stills of 2,000 lbs. each. The cost of repairs are trifling.

Guttmann's batteries are usually made in double sets, as shown in Fig. 133, so that twice six pipes are mounted in one water tank. If

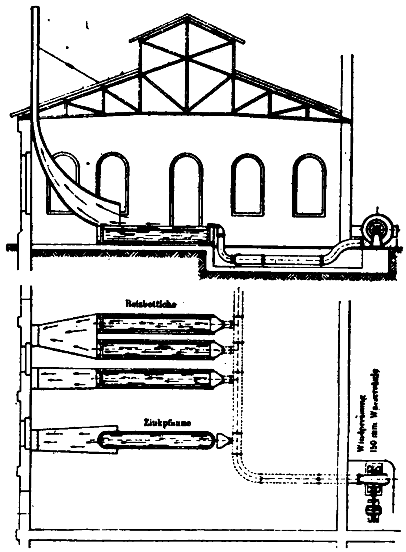


FIG. 138. REMOVING ACID VAPORS.

the tower attached to such a double battery is 2 ft. 4 ins. in diameter and 10 ft. high, a second double battery may be connected to it.

Weldon's apparatus for regenerating peroxide of manganese is shown in Figs. 135–137.

Finally we want to mention in this chapter the arrangement of a plant for removing acid and zinc vapors, a problem which is of importance to galvanizing plants. Draft applied through funnels provided over the tanks is not satisfactory. Fig. 138 shows a plant in which compressed air is blown over the tanks through a stack and this arrangement gives perfect satisfaction. The air nozzles are ½ in. high and have the width of the boxes.

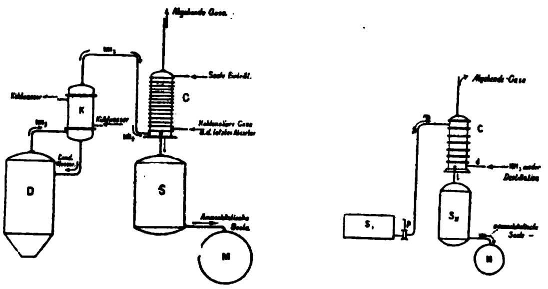
CHAPTER XVII.

LAYOUT, DESIGN AND CONSTRUCTION OF ALKALI PLANTS.

The travel of the brine in the manufacture of Solvay soda is shown in Fig. 139. The salt is dissolved in *SI* and the solution pumped by means of pump *P* to column *C*. Here it is saturated with ammonia entering through *d*.. In order to effect perfect re-saturation with salt the solution passes to *SII* and from here to egg *M*, wherefrom it is pressed to the absorption apparatus as required.

The distillation and absorption of ammonia in the Solvay process is illustrated in Fig. 140, the Solvay tower in Fig. 141.

An electrolytic plant for the production of bleaching solution,



FIGS. 139–140. SOLVAY SODA PLANT.

system Siemens-Schuckert, is described below. The construction and operation of this apparatus is as follows:

The electrolyzer, which is specially built for the purpose *is noted for its excessive simplicity*. It consists of a tank, the walls of which consist of concrete, cemented brick or sandstone and the bottom consisting of an iron plate. A little way above the bottom, there is mounted, electrically connected with same, right across the entire bath, a net of iron wire mesh, which keeps the diaphragm in place. By this means the entire inside of the bath is divided into an upper and a lower chamber. The latter is used as a kathode chamber in which the solution of caustic soda accumulates and from where it may be drawn off by means of a faucet. The upper chamber of the bath is used for an anode chamber and is closed up gas-

tight, by an insulating cover. In this anode chamber the anodes which are made of carbon are introduced through the cover, and are so mounted that they lay horizontally over the diaphragm. The cover is further equipped with a valve for the removal of the chlorine gas which accumulates below the same, and with a pipe connection for filling the bath with the solution of sodium chloride. The bath is heated by means of hot water or the hot solution of sodium-chloride.

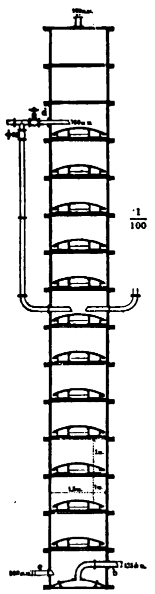


FIG. 141.
SOLVAY TOWER.

The electrolyzer cells are furnished in various sizes and are carefully designed and tested in detail.

The entire apparatus tends to promote and to facilitate the formation of layers which takes place in the course of the electrolysis and is necessary for a high efficiency.

The operation which is performed in the apparatus is as follows: If the cell is filled with the saturated, hot solution of sodium chloride and the electric current is turned on, chlorine gas is generated at the anode, which ascends and accumulates in the free space above the anode, while only a very small part is kept at the solution of sodium chloride directly surrounding the anode. At the same time at the kathode sodium metal is formed, which, however, coming in contact with the surrounding water, immediately combines with same to a strong solution of caustic soda. Here there are two different layers of liquid, one, light, on top containing chlorine, and the other of higher specific gravity containing caustic soda, below. The two liquids are separated by the diaphragm and cannot mix directly. The solution of sodium chloride, above the diaphragm, filters in consequence of the hydrostatic pressure of the liquid above, through the diaphragm and carries down with it the caustic soda above the diaphragm, concentrating by passing the wire mesh and accumulates at the bottom of the tank as a comparatively strong solution of caustic soda. On account of the layers thus formed by the diaphragm the two products gained from the electrolysis, chlorine and caustic soda are entirely separated and can further be separately utilized.

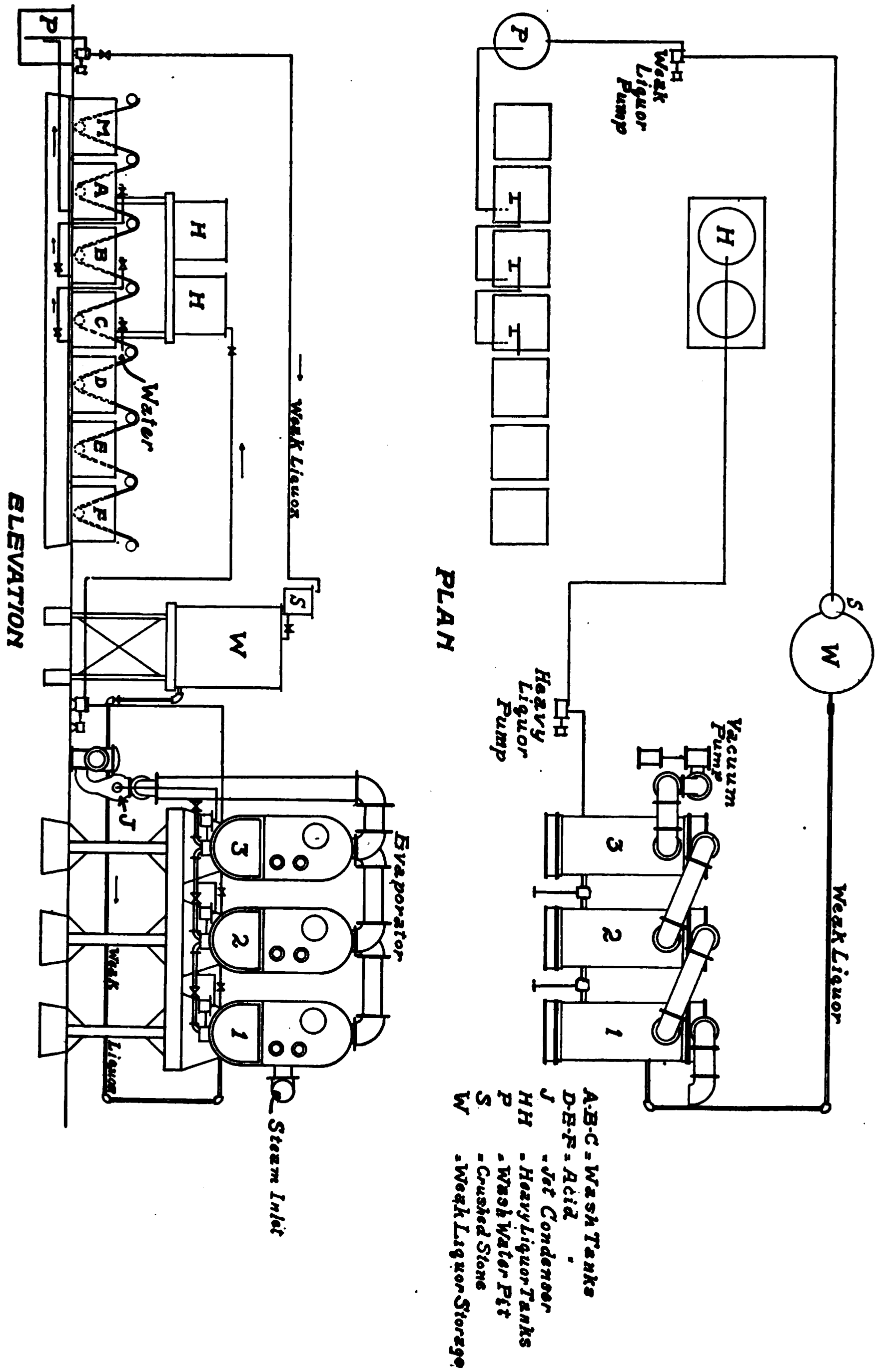


FIG. 142. SODA RECOVERY IN SODA PULP PLANTS.

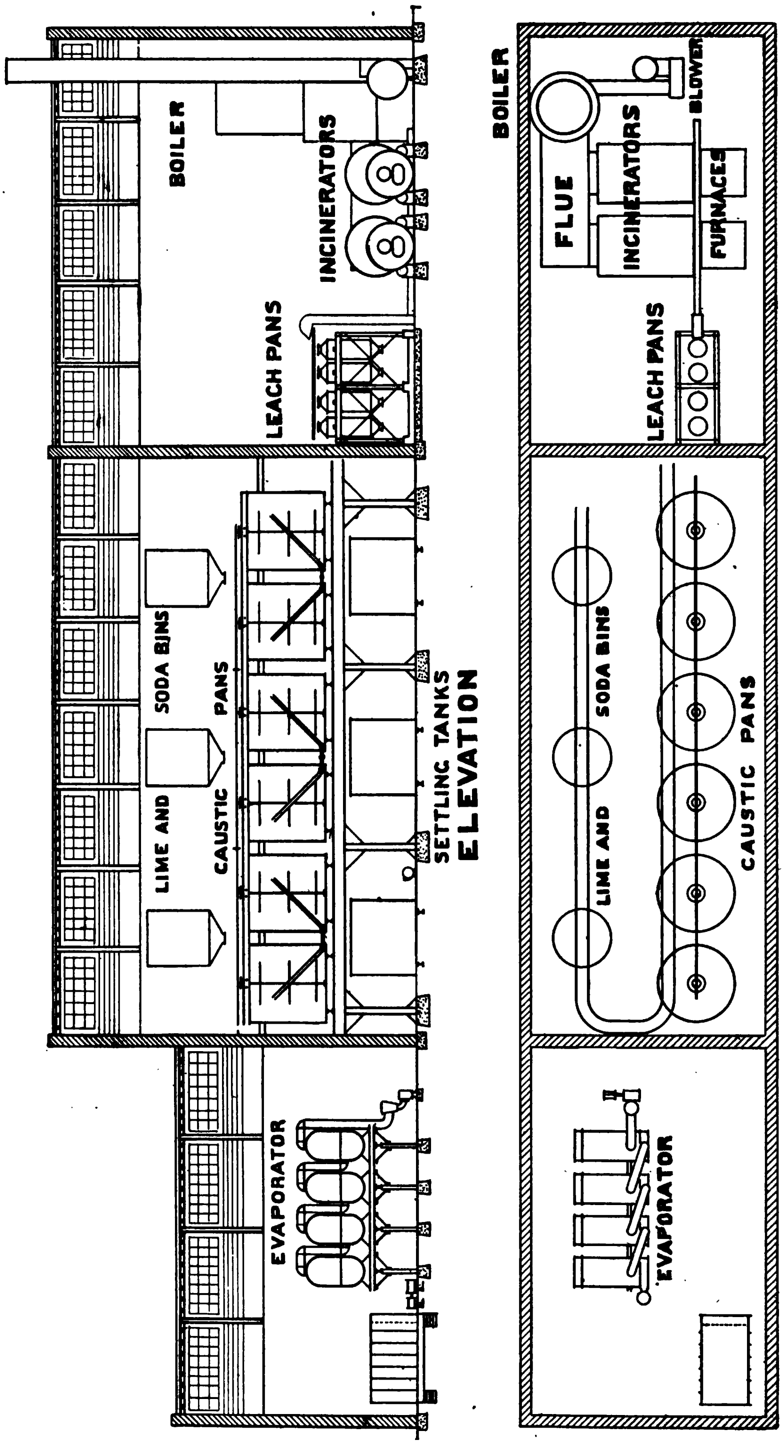


FIG. 143. SODA RECOVERY IN MERCERISING WORKS.

A soda recovery plant as used in soda pulp plants is shown in Fig. 142, while Fig. 143 illustrates a soda recovery plant as operated in mercerizing works.

CHAPTER XVIII.

LAYOUT, DESIGN AND CONSTRUCTION OF PAINT MILLS.

Fig. 144 represents a combination of paste mixer, cooler and paste mill, and shows their position in relation to each other when in use. This arrangement is a very popular one in the paint trade for mixing and grinding combination leads and heavy paste paints. A batch of material is first mixed in the upper mixer, is then discharged into the cooler, suspended from the ceiling, this cooler acting as a feeder for the mill through which the product is to be ground. This sketch represents 34 × 20-in. mixers, 30 × 20-in. cooler and 30-in. water-cooled mill.

Fig. 145 represents a combination of heavy paste mixer, mounted on a platform, and lead or heavy paste mill, supported by the floor of the factory: a very convenient arrangement where floor height will allow for it. This sketch represents 36 × 24 mixers in connection with a 36-in. water-cooled lead mill.

Fig. 146 shows the layout of a liquid paint grinding plant, in which material is first mixed on mixer platform, ground through a liquid mill, and discharged into storage tanks, on the storage tank platform, and from these tanks distributed by a pipe line to tinting tanks throughout the factory.

Fig. 147 represents two whiting chasers.

Fig. 148 shows a plant for mixing, grinding, blending and packing combination colors, kalsomine, dry materials, etc.

Fig. 149 shows general arrangement of pulverizing, elevating and bolting dry materials.

Fig. 150 shows plant for crushing, grinding, bolting and packing dry materials.

Fig. 151 shows a dry grinding plant.

The installations illustrated in Figs. 144 to 147 were designed by the Kent Machine Co., Brooklyn, N. Y., the ones shown in Figs. 148 to 151 by Chas. Ross & Sons Co., of Brooklyn, N. Y.

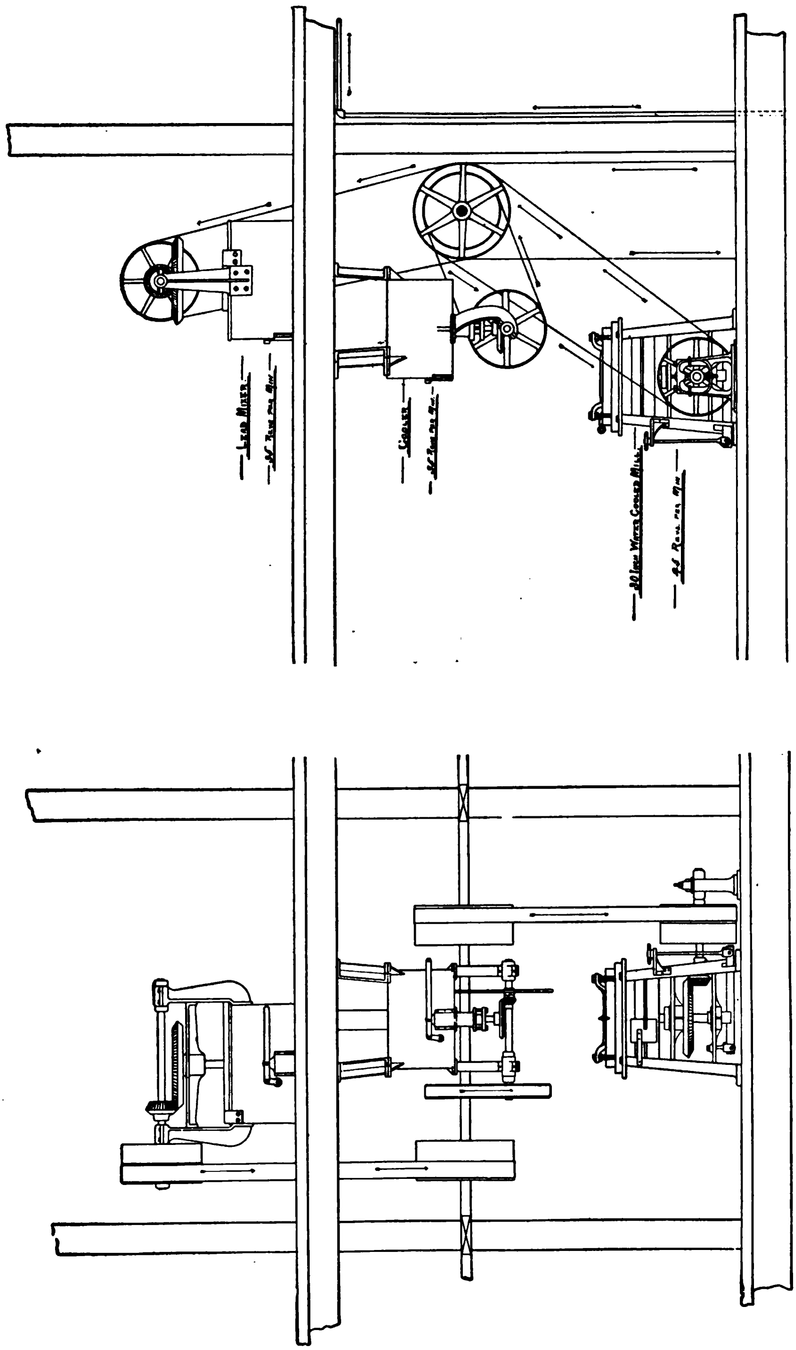


Fig. 144. Paste Mixer, Cooler and Paste Mill.

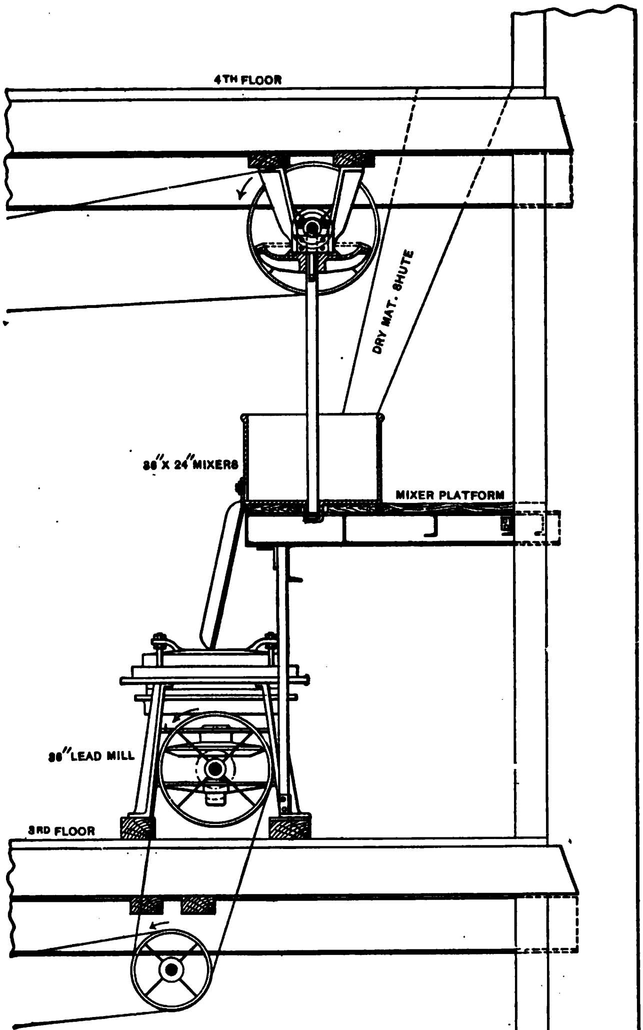


FIG. 145. MIXTURE AND LEAD MILL.

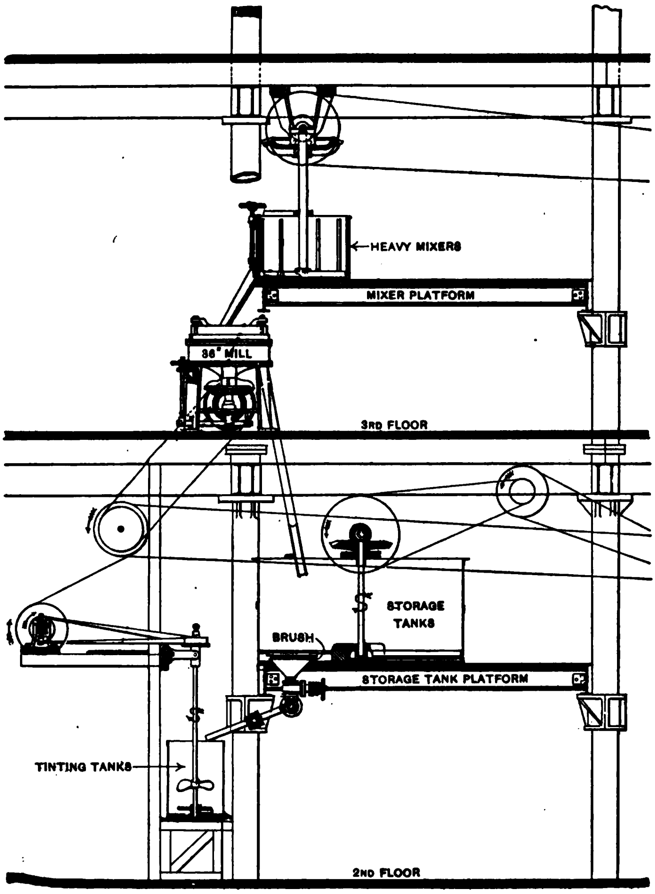


FIG. 146. LIQUID PAINT GRINDING PLANT.

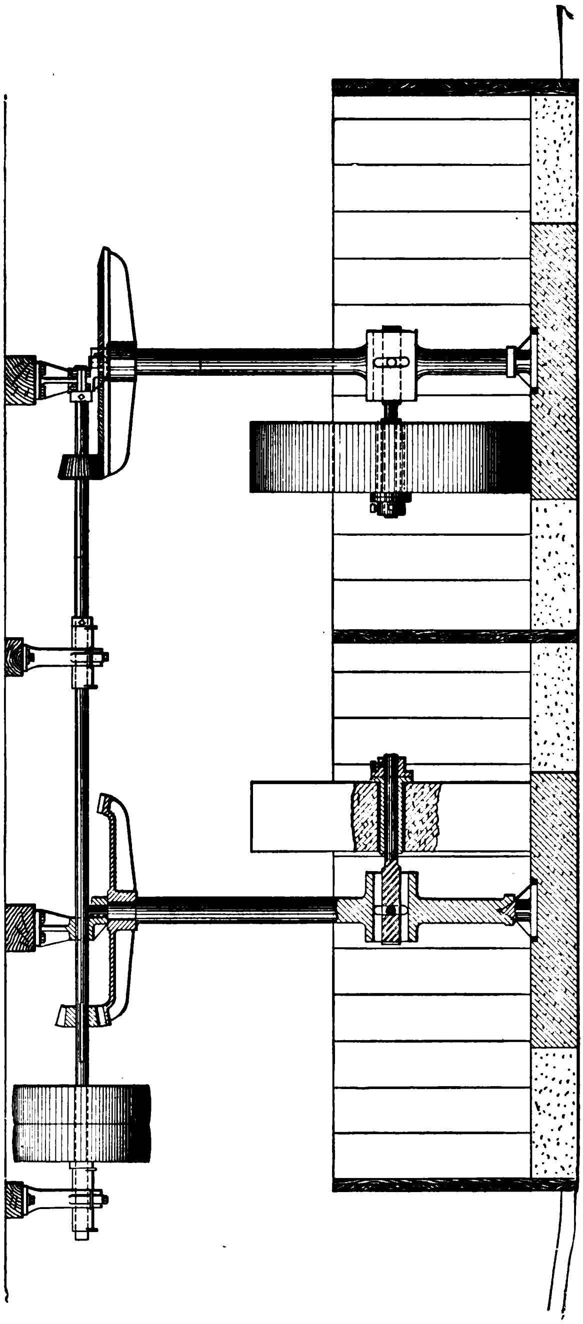


FIG. 147. WHITING CHASERS.

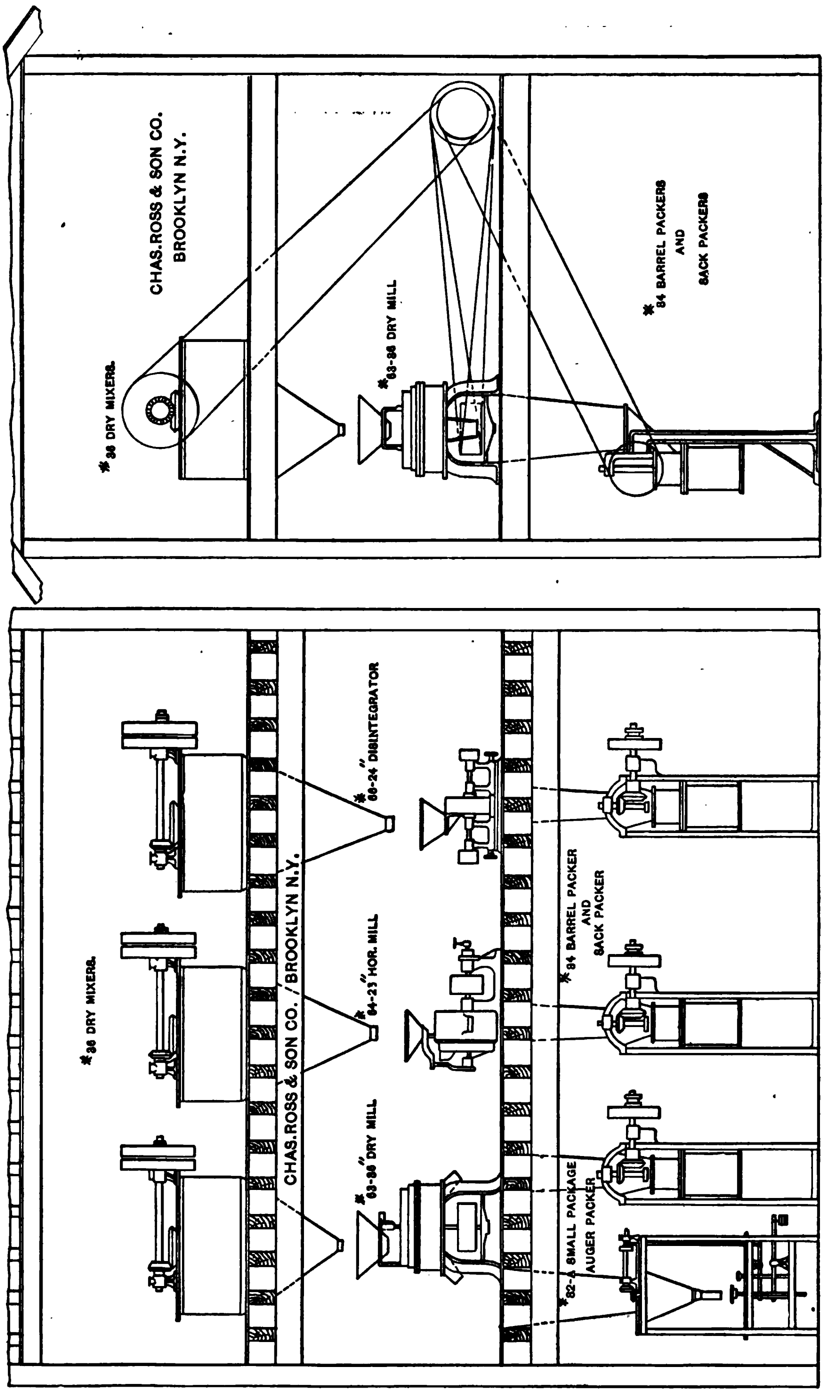


FIG. 148. PAINT MILL.

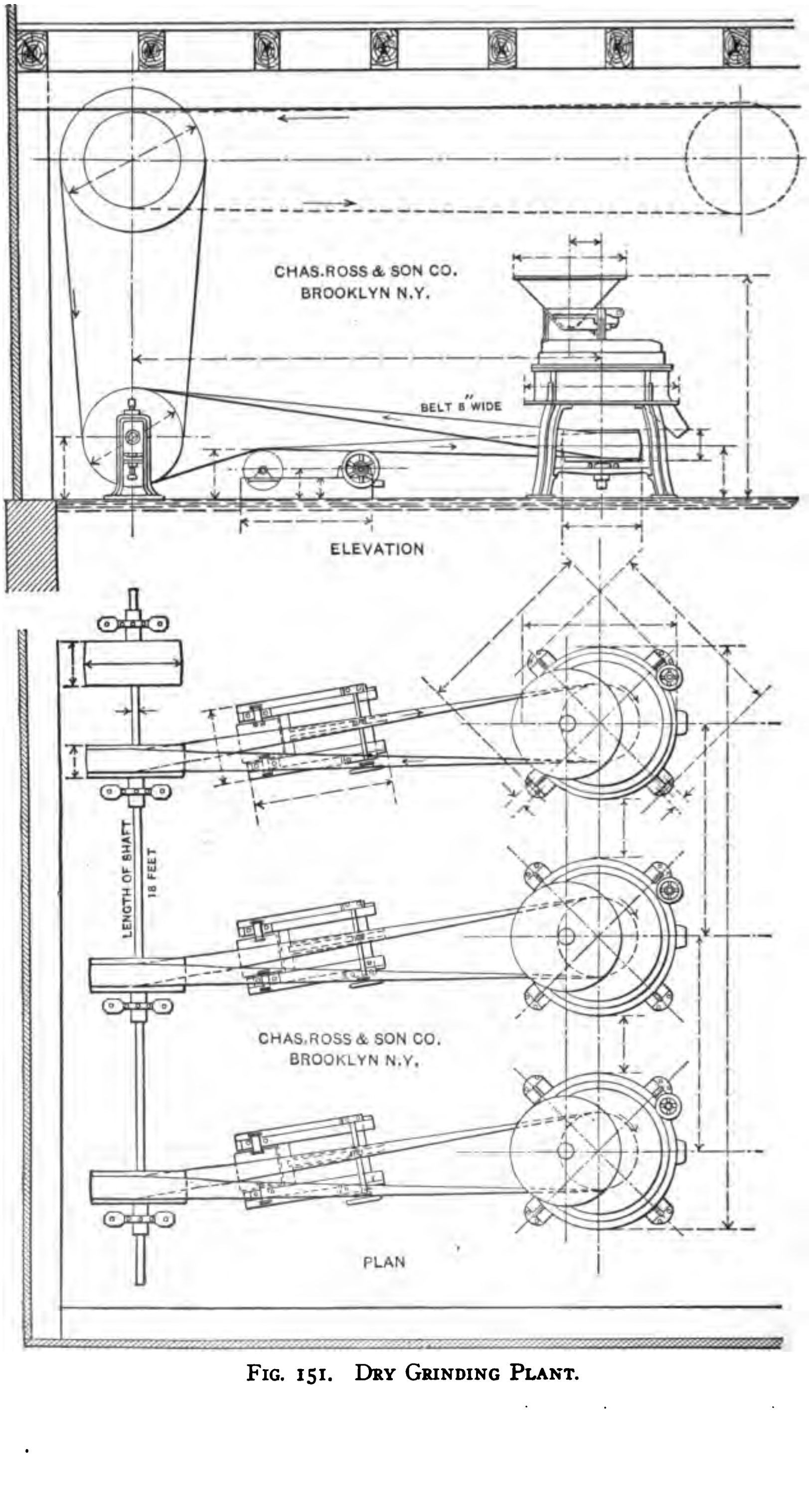
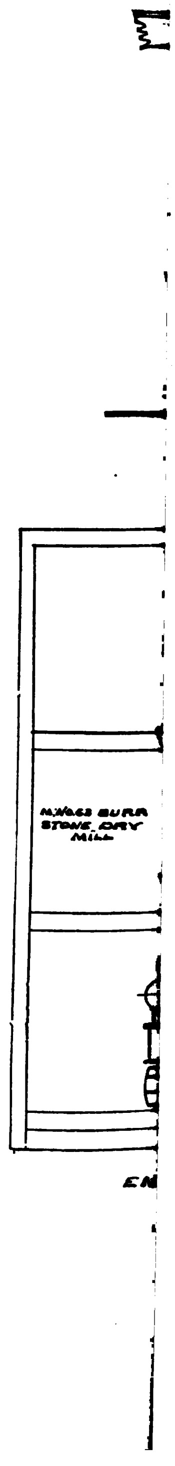


FIG. 151. DRY GRINDING PLANT.

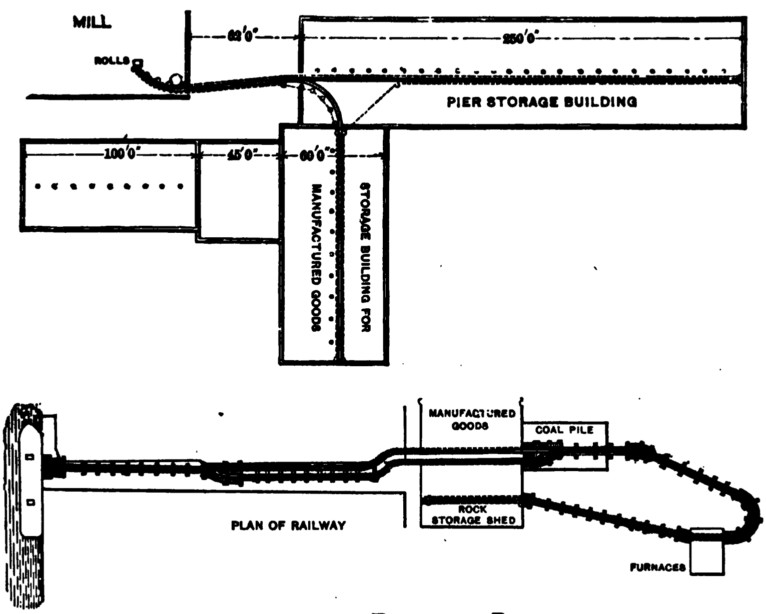

M.W.&S BURR
STONE DRY
MILL
EN

CHAPTER XIX.

LAYOUT, DESIGN AND CONSTRUCTION OF FERTILIZER PLANTS.

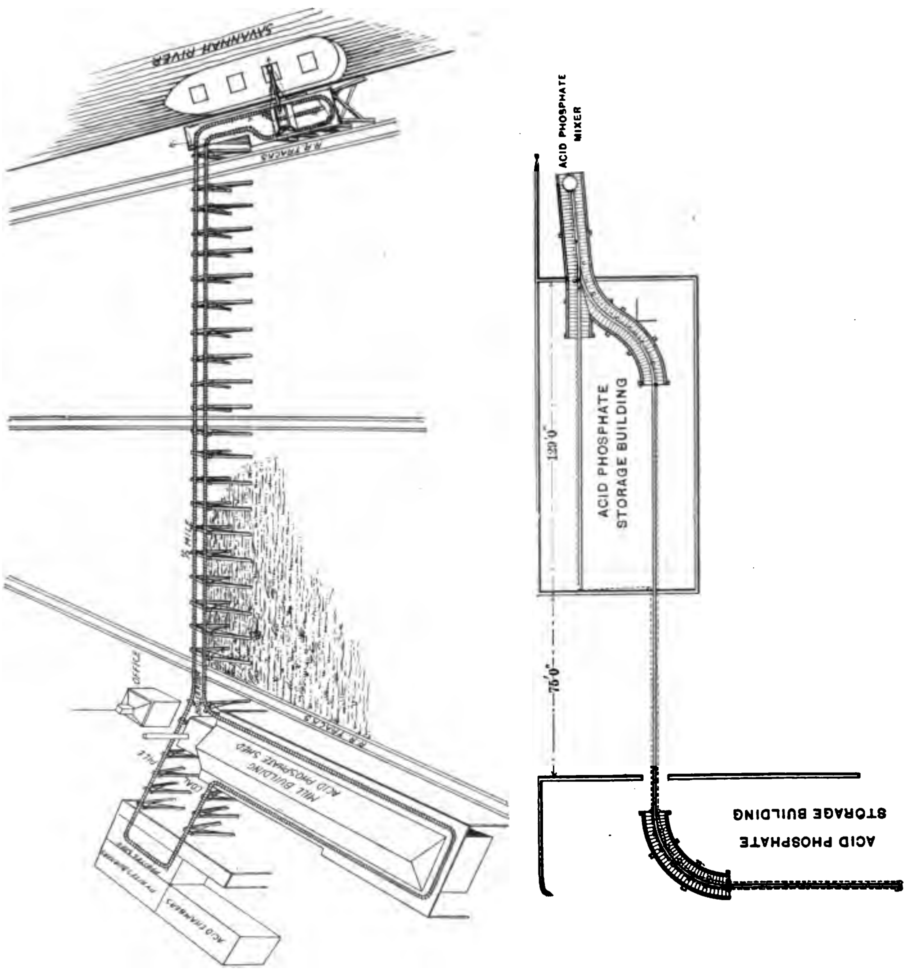
Since it is not the object of this book to discuss the manufacturing processes we will show in this chapter a few layouts only of fertilizer plants. These are illustrated in Figs. 152 to 155.

The collection of dust, the removal of obnoxious vapors and the



FIGS. 152, 153. FERTILIZER PLANTS.

discharging of the superphosphates are important steps in this industry. An Osborne dust collector is shown in Fig. 156, a condensing plant for obnoxious vapors in Fig. 157 and a discharging installation, system Milch, in Figs. 158 to 159.



FIGS. 154, 155. FERTILIZER PLANTS.

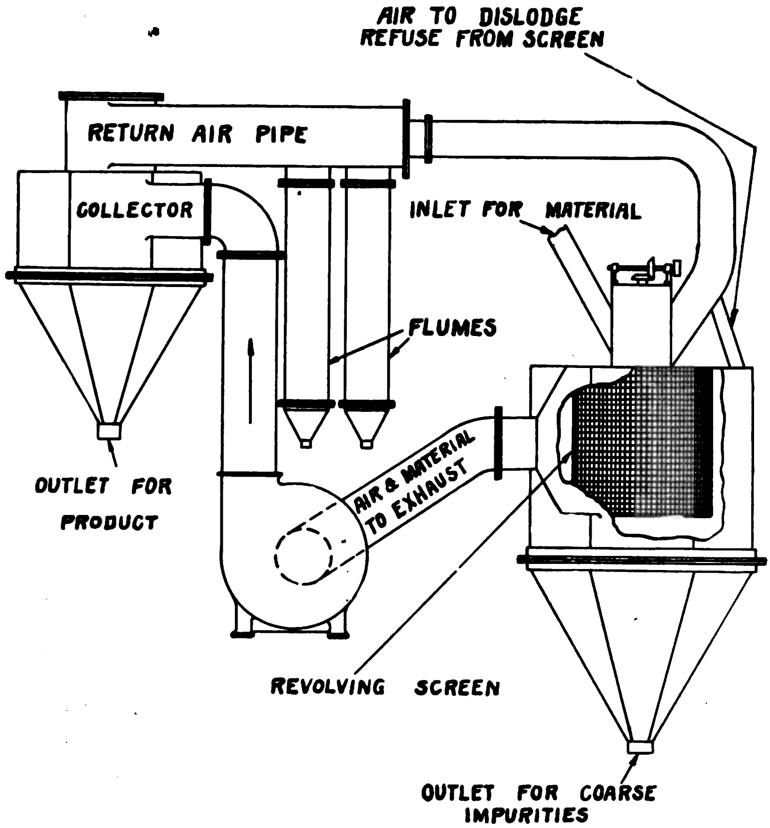


FIG. 156. DUST COLLECTOR.

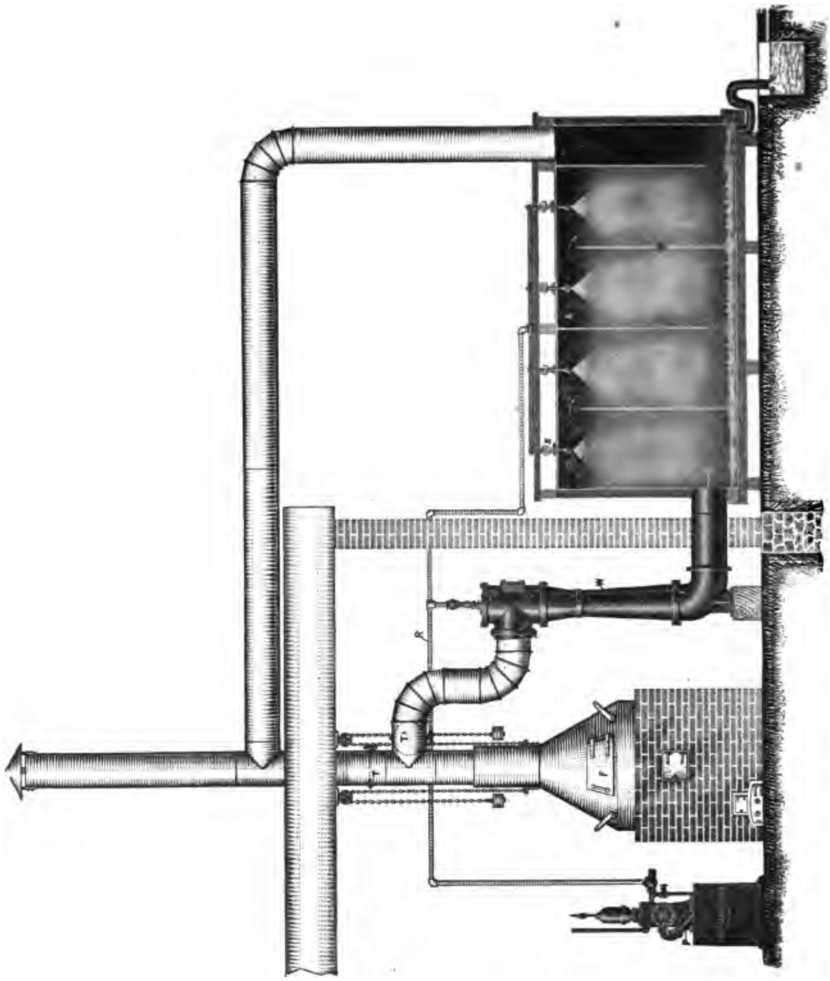
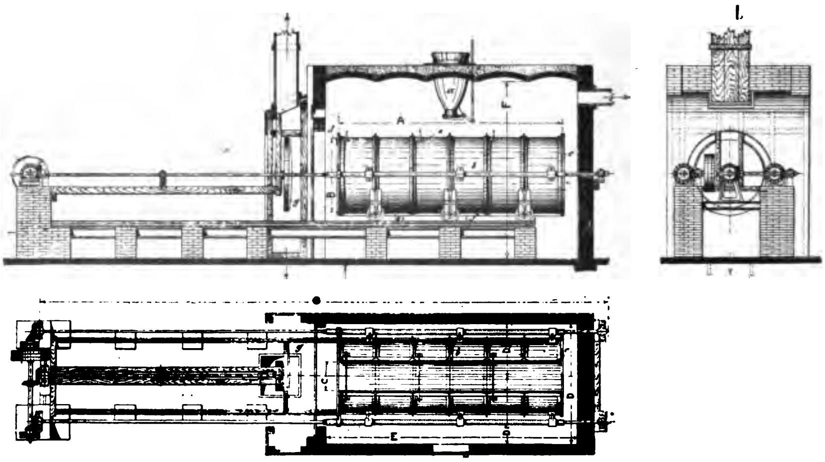


Fig. 157. Vapor Condenser.



Figs. 158–159. Phosphate Discharging Apparatus.

CHAPTER XX.

BRICK PLANTS.

A brick plant should always be located right at the clay deposit, and the machine house, dryer and kilns should be located so as to decrease the cost of transportation and conveying from the kiln through the plant to a minimum. Producer gas fired brick kilns

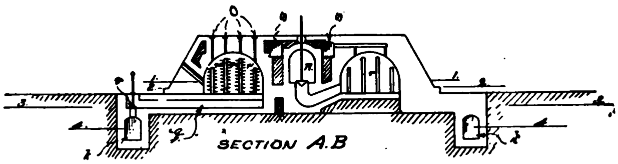


FIG. 160. PRODUCER GAS-FIRED BRICK KILN.

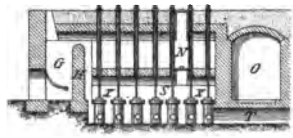


FIG. 161. PRODUCER GAS-FIRED BRICK KILN.

are shown in Figs. 160–162. A detailed description of these types may be found in Nagel, Producer Gas Fired Furnaces.

The economical performance of the drying operation being of great importance in the layout and design of brick plants, it seems advisable to devote some space to the discussion of this problem.

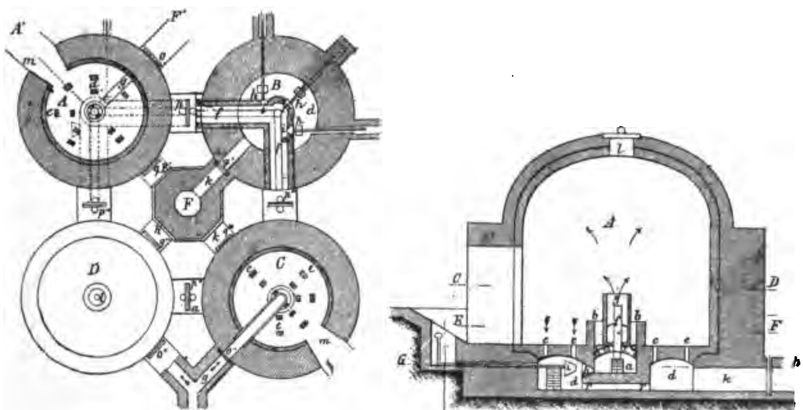


FIG. 162. STEINMANN KILN.

In the artificial drying of brick and tile, the heat for drying is supplied originally by the combustion of fuel, but it may be carried to the brick or tile in various ways, as:

1. By allowing the products of combustion to circulate among the brick, as in "water smoking."

2. By imparting the heat of the products of combustion to clean air and allowing the latter to dry the brick, as in the "hot air dryer."

3. By first using the heat to burn brick or tile in a kiln and then drawing fresh air through the cooling kiln by means of fans and

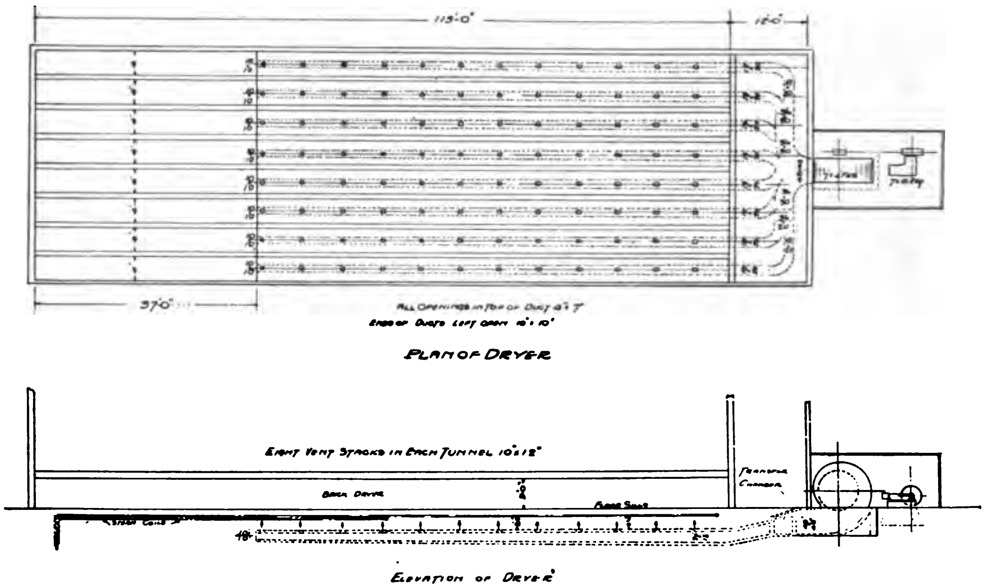


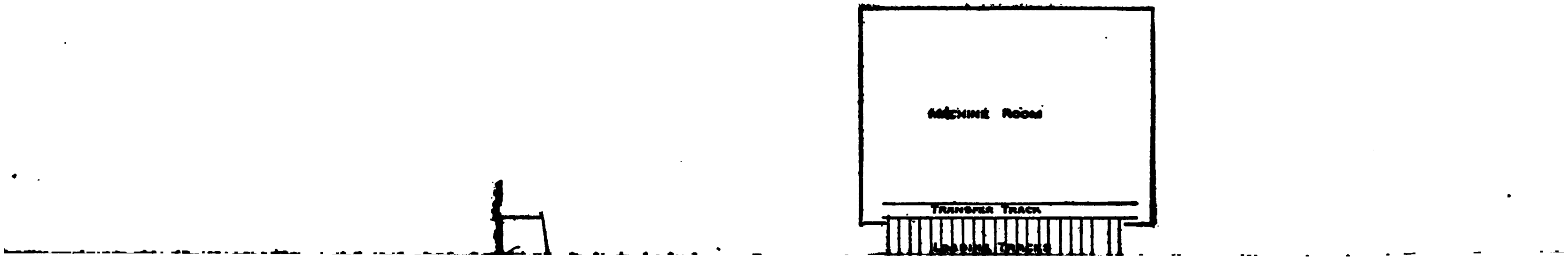
FIG. 164. HOT FLOOR DRYER WITH FORCED VENTILATION.

forcing the heated air in among the material to be dried, as in the "waste heat" process.

4. By using the heat of combustion to generate steam in a boiler and passing the steam through pipes or coils underneath the drying floor, where it heats air which then rises by its buoyancy up among the brick or tile, as in the old style "hot-floor" and "direct" dryers, and:

5. By generating steam as before, but using it in heater coils to heat air in a chamber, whence the air is blown by fans among the brick or tile, as in the modern "indirect" drying systems.

In both of the last two systems, where steam is employed, exhaust steam from an engine will do as well as live steam, providing the piping is so arranged that it can circulate freely. Exhaust steam contains from 85 to 95 per cent. of the heat originally contained in


MACHINE ROOM
TRANSFER TRACK

the live steam and it may be roughly figured that a pound of exhaust steam in condensed form will evaporate a pound of water from the brick. The heat obtained from exhaust steam really costs nothing, as it would otherwise be wasted, so that these systems may also be called "waste heat" systems. Any one of the waste heat systems may be arranged to be supplemented by direct heat from a furnace or from live steam.

In selecting a system, the waste heat systems are first to be considered, as the burning of good fuel for drying purposes alone would prove a very expensive business. If it is decided to utilize the waste heat from the cooling kilns, a fan must be employed. Waste heat dryers can be used with down-draft or up-draft kilns or round or square kilns, also with continuous kilns.

Using Waste Heat from the Kilns.—We illustrate an arrangement for down-draft round kilns in Fig. 163. A Green fan draws the heated air from the cooling kilns through underground, brick-lined ducts and forces it into a tunnel running transversely to the

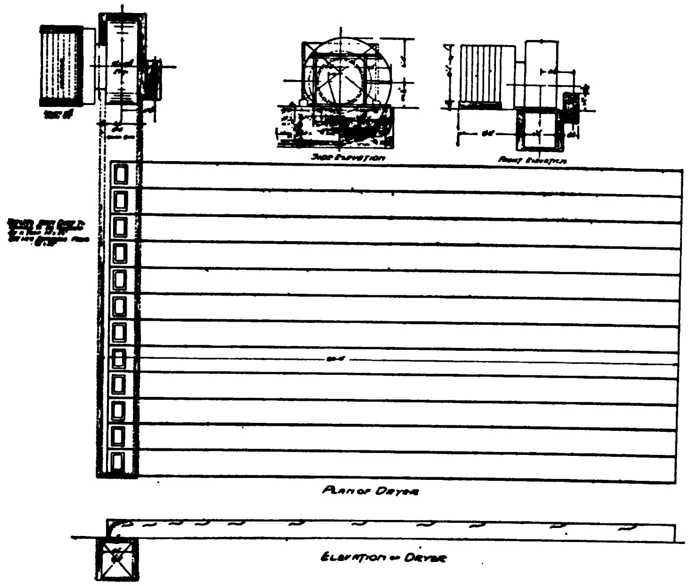


FIG. 165. BRICK DRYING ARRANGEMENT.

tracks in the dry house. From this transverse tunnel the air is admitted through dampers into a longitudinal tunnel under each track. These tunnels have openings on top under the tracks and become

more shallow as they proceed, terminating altogether at from one third to two thirds the length of the drying shed. At the farther, or cooler, end of the dryer is another transverse tunnel in which are openings for the escape of the cooled and moisture-laden air. The loaded trucks from the machine room are pushed into the dryer at this end, and are slowly advanced as new trucks are added, until they emerge from the hot end of the shed onto the "cooling tracks,"

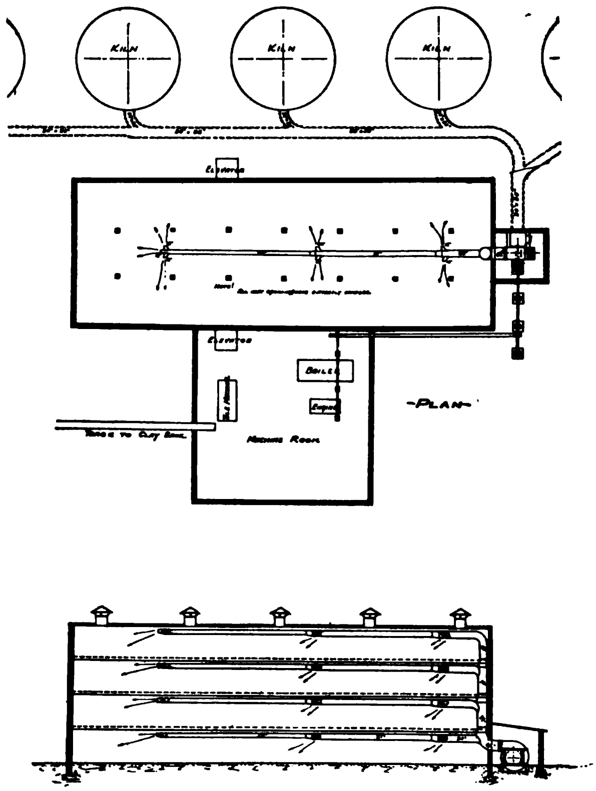


FIG. 166. WASTE HEAT DRYER.

bone dry and ready for burning. This is known as the "progressive" system of drying.

Drawing cold air through the kilns hastens cooling, so that in this system the kiln capacity can be increased about 20 per cent. Where the heat from the kilns proves insufficient it can be supplemented by heat from furnaces, or from exhaust or live steam, as mentioned later on, provided suitable flues and by-passes are arranged.

Another indirect brick dryer is shown below in which the fan outfit is placed at the end of the dry-house in the middle, shortening somewhat the distance which the air has to travel through the ducts. This is an old hot-floor system built over. There are steam coils under the entire floor, but, with natural ventilation, drying was too slow, and so the fan and flues were installed to distribute air under the floor, whence it blows up and is heated by the steam coils before passing among the brick.

In Fig. 164 is shown an indirect exhaust-steam brick dryer put in for the Goshen Brick Company, of Goshen, N. Y., in which no special ducts underneath the tracks are employed. There is one transverse duct under the end of the dry-house and from this the air is admitted through dampers to channels about three feet deep, running between the tracks the entire length of the house. As the

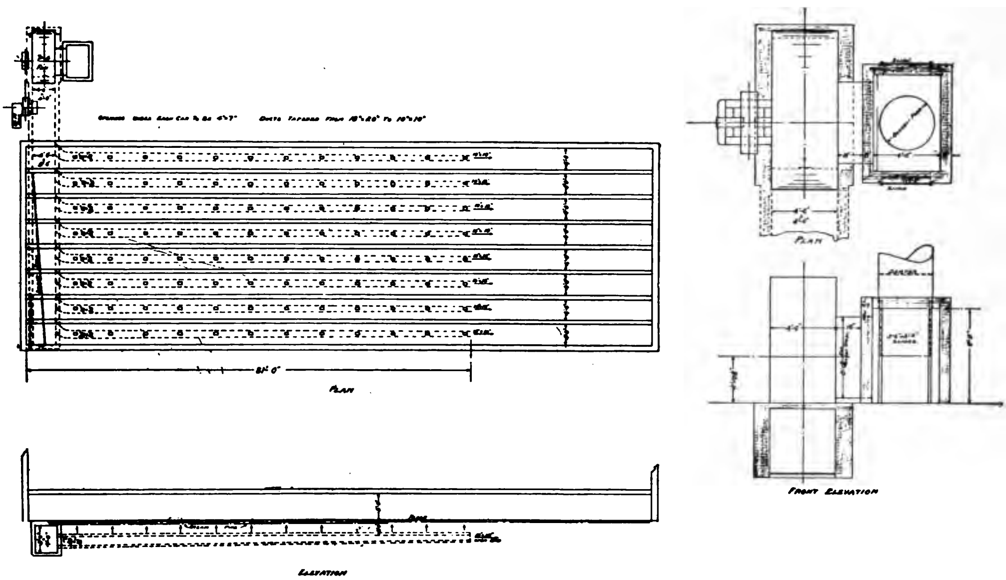


Fig. 167. Waste Heat Brick Dryer.

air escapes from the transverse duct it is turned by deflectors down through the channels. This dry-house contains twelve tracks.

A brick drying outfit for utilizing the waste heat from the kilns that are cooling is shown in the installation of the Spencer Brick & Tile Co., Fig. 166. It will be noticed that the dry-house is located between the machine room and the kilns and also that it has four stories or floors. The fan is located at one end of the dry-house

and draws the air from the kilns through underground ducts and then forces it into a system of piping which distributes it to the several floors of the dry-house. One large riser or vertical flue extends from the outlet of the fan up through the different floors of the building and from this on each floor other flues branch off, running nearly the entire length of the floor, and having outlets at three different points where the heated air is blown out on both sides. After the air has taken up moisture from the bricks, it escapes through ventilators in the roof of the building. The clay is brought into the machine room from the clay bank by a small railway. From the machine it is delivered onto an elevator which raises it to the several floors, while the dried tile are lowered from the floors by an elevator on the opposite side of the building, to be piled and stacked in the kilns. As the kilns supply all the heated air needed for drying, it was considered economical to use no more steam than necessary for the engines, and the fan is therefore driven from the large engine which drives the tile machine. The arrangement for shafting and belts for accomplishing this may be noted on the drawing.

Different varieties of clay and bricks made by different processes require special treatment as regards the rate of drying. With the apparatus just described, this is at all times under the control of the operator, who can regulate the amount of air going into each tunnel by means of the dampers, can change the speed of the fan or can temper the air by mixing fresh, cold air with it or by bringing back and sending through again part of the heated moist air. The proper temperatures and rapidity of air change, as well as the proportions of the tracks, trucks, fans and air ducts and the method of piling the bricks, are points which have to be learned by experience with various clays.

CHAPTER XXI.

LAYOUT, DESIGN AND CONSTRUCTION OF SUGAR AND ALCOHOL PLANTS.

The layout of sugar plants is shown in Figs. 168 to 170. Since there is nothing difficult about these layouts we will not dwell upon their description and will proceed to the description of an interesting part of sugar manufacturing, namely the revivification of charcoal.

The Weinrich Improved System of Reviving Bone-Black.—The usual mode of reviving bone-black consists in converting into carbon by destructive distillation the organic impurities absorbed by the bone-black during its use, and which are not removed by washing. This is done in retorts at a red heat under careful exclusion of air.

It is known that this mode of revivification involves a number of disadvantages, viz.:

1. The carbon originating from the organic impurities accumulates gradually and chokes the pores of the bone-black, and thus impairs its efficiency, until it becomes practically useless.

2. By this method of reviving certain inorganic impurities accumulate, especially iron and sulphide of calcium, which are very injurious to sugar solutions.

3. The original percentage of carbonate of lime (which forms a part of the mineral framework of new bone-black, and which is essential where the so-called "bloom" in sugars is required), decreases gradually by the present method or revivifying, and sometimes disappears altogether, partly on account of excessive washing with boiling water which frequently turns acid and partly on account of overburning in kilns.

4. An entirely uniform burning in kilns is impossible, and therefore at every operation some of the bone-black will be overburned and some underburned. Through overburning the mineral framework of the bone-black will shrink gradually and will thereby lose in porosity, and, consequently, in efficiency.

5. The great wear and tear on the kilns, and—

6. The considerable use of fuel, owing to the fact that the bone-

black has to be brought to and maintained at a red heat for some time.

The Weinrich System of Revivifying Bone-Black (Fig. 171) avoids all these serious disadvantages, and is, besides, very simple and cheap in its application, and sure in its results.

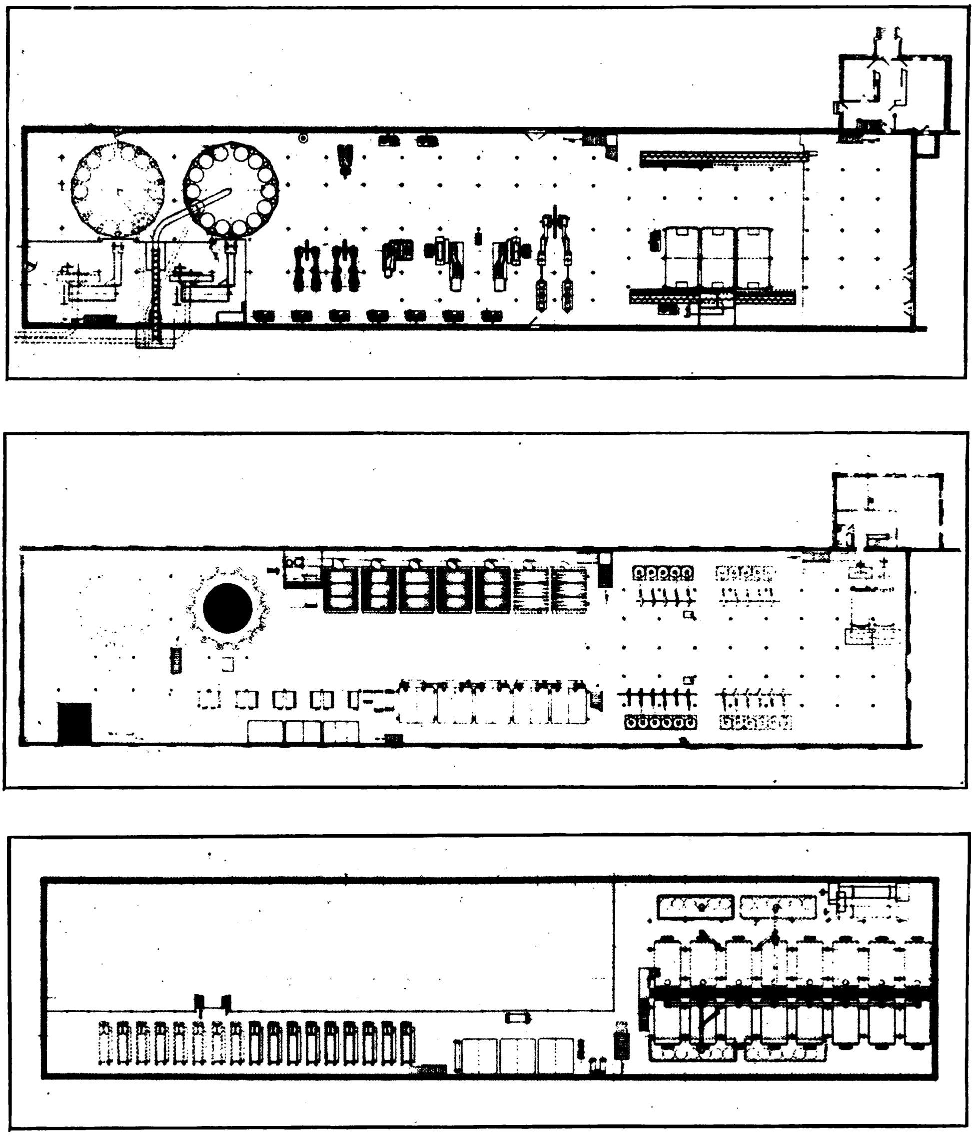
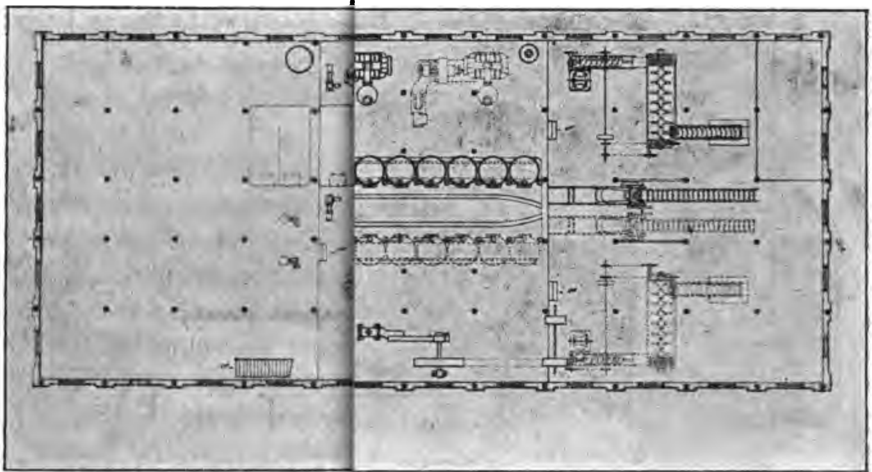
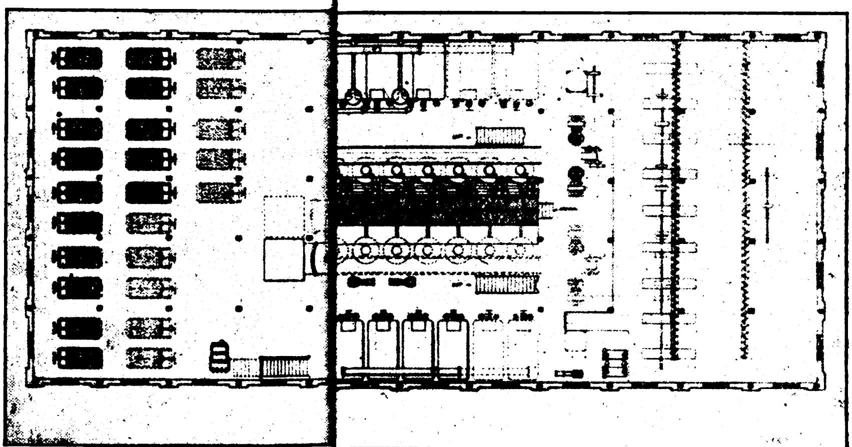


FIG. 168. SUGAR PLANT.





It is not, like the kiln-work, based upon the principle of destructive distillation, but rather upon the principle of oxidation. In carrying out this principle, the bone-black is heated moderately in a suitable apparatus of simple construction and exposed simultaneously to a regulated draft of atmospheric air, whereby the oxygen of the air is enabled to penetrate into the finest pores of the heated bone-black, thus burning off the organic impurities.

Any contents of sulphide of calcium will oxidize into sulphate of calcium, and any contents of soluble iron will oxidize into insoluble oxide of iron.

It has been found that these organic impurities will burn off at a much lower temperature than carbon, and since the temperature can be regulated to a nicety, a line can be easily drawn within which all the organic impurities will burn off before any of the underlying carbon is affected. Should there be any excess of carbon accumulated during former revivifying in kilns, then this excess can be removed simultaneously with the organic impurities, by simply regulating the temperature, draft of air and feed of bone-black, and without bringing the bone-black to a red heat.

The revivification is done in about thirty minutes. Feed of the bone-black, temperature and admission of air are regulated by simple devices and the whole work is easy to superintend. If sufficient time is allowed it is feasible to revivify ordinary refiners' char at a temperature of 400° to 450° F. In practical work, however, to make use of the full capacity of the apparatus, it is advisable to keep the temperature of the outgoing char between 500° and 600° F. for simply revivifying, and at 700° to 800° F. if desired to reduce the percentage of carbon in the bone-black. The advantages of this new system over the kiln-work are obvious:

The mineral framework of the bone-black retains its original porosity on account of the mild heat applied, and its original percentage of carbon remains always the same because the organic impurities become completely removed through oxidation. The contents of carbonate of lime remains nearer to its original percentage.

The bone-black consequently always acts as though new, even in the filtration of very impure solutions, and only the loss through dust, which is not greater than with kiln-work, has to be made up by new char.

The use of fuel is only about two thirds of the amount required

for kiln-work. The washing of the char in the filters can be discontinued as soon as most of the salts are washed out, as it is cheaper and time-saving to burn off rather than wash out the remaining organic impurities.

On account of the mild heat applied the wear and tear of the apparatus is much less than that of kilns.

These advantages mean therefore greater efficiency of the bone-

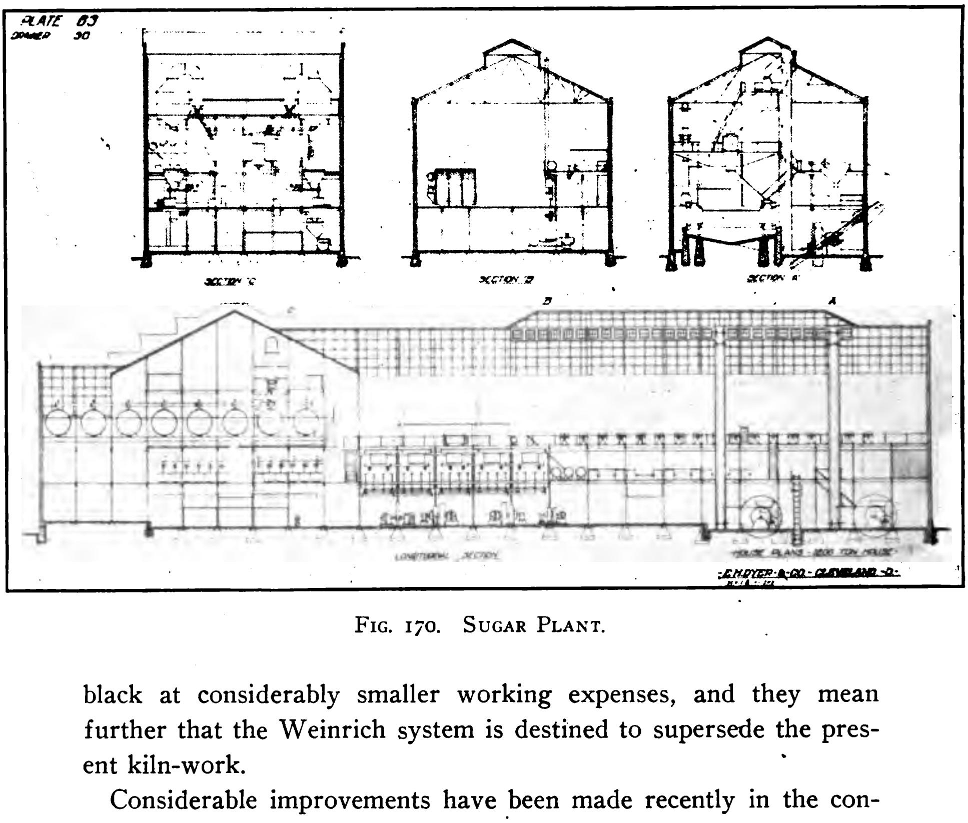
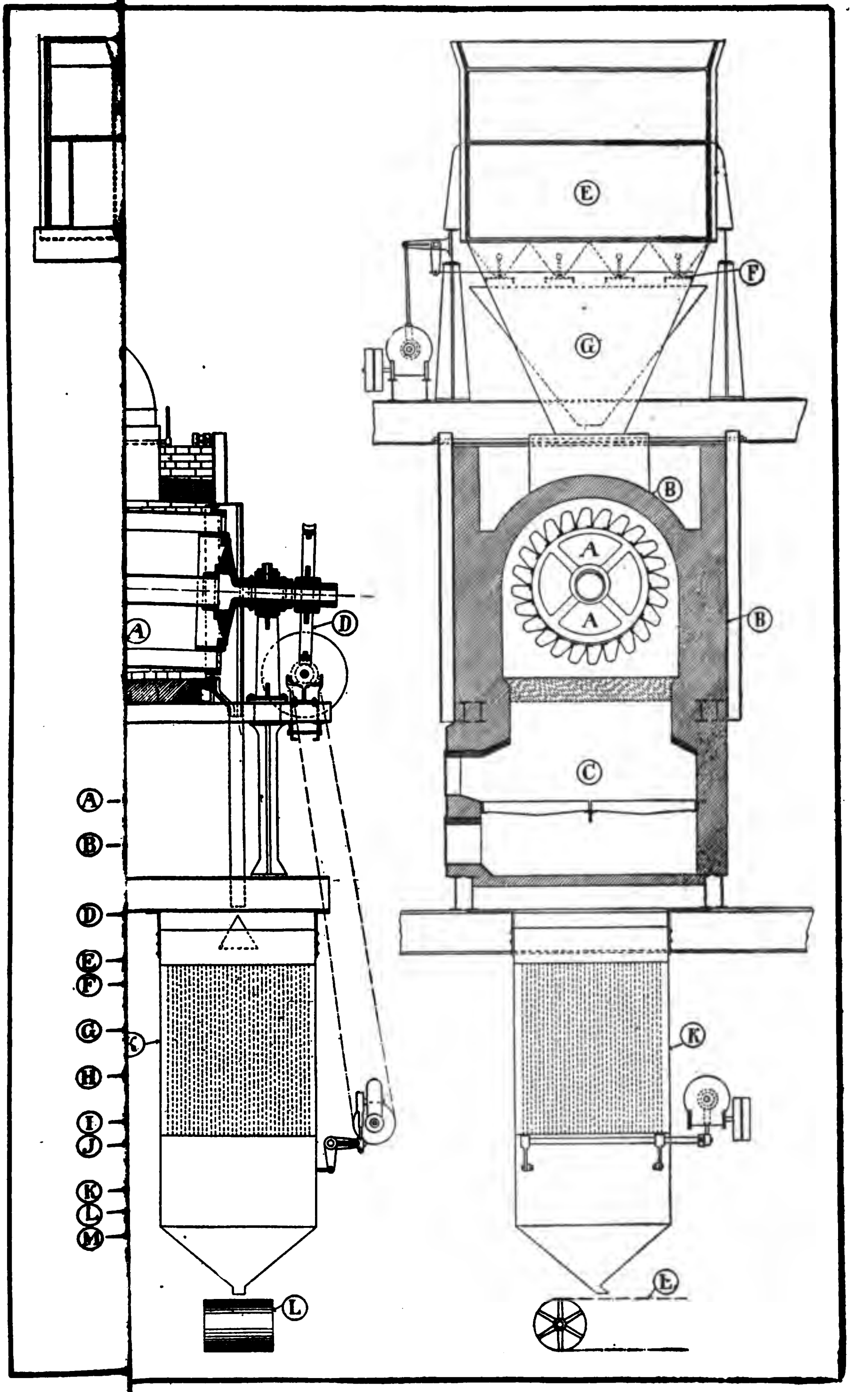


FIG. 170. SUGAR PLANT.

black at considerably smaller working expenses, and they mean further that the Weinrich system is destined to supersede the present kiln-work.

Considerable improvements have been made recently in the construction of the apparatus for carrying out this system of which we hereby give an illustration. The bone-black after having passed through the drier *E,* which is heated by the waste gases, enters the revivifier consisting of a slowly revolving corrugated drum *A,* resting upon heavy bearings and rollers. The drum is incased by brickwork, except at the ends where it is incased by hoods.

The corrugation is obtained by a number of U-shaped troughs secured to two head pieces and an iron frame-work connecting these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head pieces. Beneath the feed end of the drum is placed the furnace *M*. The fire and gases from the furnace heat the exterior of the drum and then pass through the preliminary drier.

The char dropping from the drier into the drum is heated up at once, and alternately lifted and dropped by the troughs, acting as buckets. During the revolutions of the inclined drum the bone-black will be advanced slowly towards the lower end and heated up to the desired temperature and exposed to a counter current of air. It will then drop into the cooler from which it runs continuously, ready for use again. Instead of the drier and cooler shown on this drawing any other suitable construction may be used.

The apparatus serves also to good advantage in the revivification of filtering material other than bone-black, especially of fuller's earth and of "infusorial earth," also for simply drying other materials—for instance, coal, ore, sand, beet-pulp, brewers' grain, etc.

Among the advantages of this new apparatus may be noted the following:—(1) The drum being composed of U-shaped troughs offers fully double the heating surface of a regular cylinder, whereby more material can be treated in such a drum without heating the drum to a higher temperature than when using a smooth drum. (2) There are no rivets exposed to the fire or the heating gases. (3) If a trough needs renewing it can be quickly replaced by a new one with comparatively little trouble or expense. (4) By placing the furnace beneath the feed end of the drum, where the material is comparatively cool, the inflowing char will take up heat readily and will prevent the overheating of the troughs above the fire.

In this way the whole drum will be kept at a uniform and moderate temperature, and its life will be greatly prolonged.

Alcohol.—The general handling of the product is as follows: The residuum is delivered in barrels. The barrels in question are emptied and washed at *a* (Fig. 172), the molasses runs into a reservoir *b*, which is well beneath the level of the ground, and from there it is raised to the top of the distillery by the use of a so-called chain pump *b'*. From the upper reservoir *b''*, the product falls by gravity to the diluting tanks *c'c''*, where sulphuric acid is added and from there into the boiling receptacle *d''*, in which the ebullition is continuous, this operation having for its object the so-called denitration of the molasses: the boiling liquid is at the time

sterilized. After leaving this tank, the boiled molasses is diluted in *d'''* with warm water *m* from the condensers connected with the rectifiers. Then follows an average temperature of 80° to 85° C. (176° to 185° F.) sufficient to assure a satisfactory sterilization of the wort. There follows a gradual and methodical cooling in a special tubular refrigerating appliance *d'* and *d''''* arranged in such a manner that the denitration of the molasses is accomplished with the expenditure of a very limited amount of calories. The work thus prepared is sent in a perfectly pure condition, that is to say free from all objectionable germs, to the fermenting vats *f*.

The problem that is now in view is to create a powerful, pure and active fermentation. To accomplish this, special pure ferments are prepared in the apparatus shown in *e*. The apparatus carefully sterilized with steam, at 120° C. (248° F.) is filled with sterilized

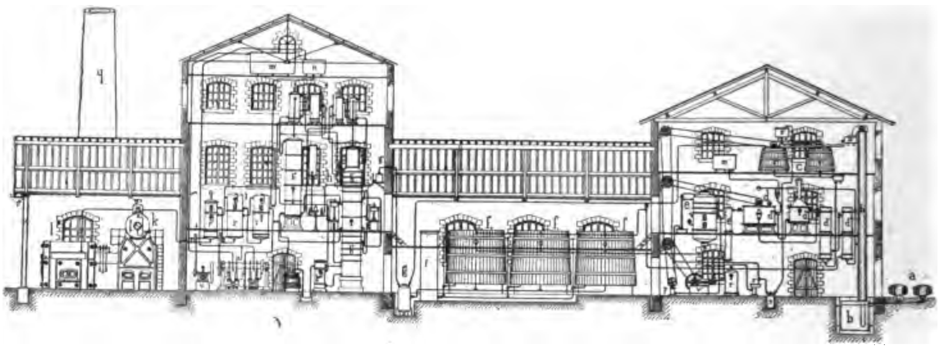

FIG. 172. ALCOHOL DISTILLERY.

molasses cooled at *e'* and sprinkled or fed with pure ferment prepared in special laboratories such as the Pasteur Biological Institute. One may take daily from this apparatus four pure ferments for the requirements of the four fermenting vats, and if one is fortunate enough to secure the services of a careful manipulator for this special work, the apparatus may be kept free from all contaminations during a period of six weeks to two months. Under these circumstances it becomes no longer necessary to resort to the daily purchase of beer yeast, which represents a great saving. Furthermore, the pure ferment from the special apparatus for its production belongs to a special race, is thoroughly accustomed to a molasses environment, and will yield the maximum efficiency of alcohol, and a purer spirit, which will offer greater facility to

rectify. In the present writing, we could not possibly enter into the numerous technical details respecting the method discovered and invented by M. Barbet, by which is given to the fermentation of the molasses considerable strength or vigor requisite for the complete transformation of its sugar into carbonic acid and alcohol, without resorting—as is generally done—to saccharified corn must. This original idea in a few words consists in the peptonization of the ferment that settles at the bottom of the fermenting vats, *f*, in order to create a soluble and easily assimilated nutrient for which the ferment of the fermentation that follows has considerable avidity. Under these conditions there results an excessive fermentation. After the molasses wort has been thoroughly fermented it is pumped at *j*, and forced up to the distillation hall. The distilling apparatus shown at *h'h''h'''*, were invented by M. Barbet.

These spirits yield at once an alcohol at 96° to 97° Tralles, which may be said to be the highest known purity possible to obtain by any mode that has a practical industrial application.

It must be noted that by this continuous mode of rectification, there is no loss of alcohol, and the fuel economy is 50 per cent. as compared with the obsolete continuous methods of distillation followed by a discontinuous rectification. The residuary liquor from the Barbet continuous distillation-rectification method contains organic substances and potash salts. Formerly it was customary to work these in enormous furnaces of the Porion type which held their own for so many years, and in which there was an unnecessary waste of fuel. The Barbet method reduces this fuel consumption to zero in the following manner.

Instead of using steam direct from the boilers to boil the wort during continuous rectification, it passes first through a copper triple effect, *i*, intended to concentrate the wash or vinasse. In the first compartment *i'*, of the appliance the steam from the boiler is at 6 kilos (13.2 lbs.) pressure; the wash boils at 3 kilos (6.6 lbs.) pressure. The liberated vinasse vapor at 6.6 lbs. pressure heats the second compartment, *i''*, and produces a vinasse vapor at 1 kilo (2.2 lbs.) pressure. It is this last vapor at 2.2 lbs. pressure that heats the tubular combination, *i'''*, of the triple effect. Owing to the three successive evaporations in the appliance, the wash has diminished in volume and, instead of being at a density of 4.5° Bé., the spindle indicates 11° Bé. From this preliminary concentration,

there has followed a remarkable physical transformation to which attention should be drawn. The vinasse at 11° Bé. concentration has become *auto evaporable;* in other words fuel is then no longer needed in Porion furnaces as the heat liberated by the combustion of the organic substances is sufficient to evaporate all the remaining water. *L* is the incinerating furnace. A certain quantity of fire is needed to ignite the organic substances, and from this moment the furnace works indefinitely without fuel. In the drawing herewith the storehouses for the resulting alcohol are not shown; they are never in the same building as the distillery proper on account of dangers from fire. The foregoing description permits the reader to form a very excellent idea of the very simple operations connected with this industry.

CHAPTER XXII.

THE SCIENCE OF BUSINESS.

The leading principles of science are observation, comparison, variation and adaptation. The scientist *observes* a phenomenon, *compares* it with his former experiences and with his thoughts, and finally he *varies* the conditions of the phenomenon and his thoughts until they are *adapted* to each other, until there is a certain *harmony* without contradictions between the phenomenon and its reproduction in thought. Galileo Galilei, the pioneer of modern science, was the first who, instead of shaping the explanation of the phenomena according to preformed ideas, tried to adapt his ideas and thoughts and conceptions to the natural phenomena and to reach a harmony of his thoughts by adapting them to each other. The harmony or rather the possibility of explaining a great number of phenomena by a few simple thoughts, is the aim of the greatest scientists. Hence in a certain sense science is a continuous simplification of this harmony. The Ptolemaic system was a harmony without contradictions, but it was a complicated harmony with his assumption of an earth at rest, of a rotating sky and of individual movements of the sun, the moon and the planets. Copernicus simplified it considerably by reducing all the movements to rotations in a circle and around the axis. In the same manner Newton reduced the three laws of Kepler to the single law of gravitation. And we all are familiar with the great simplification in science that was brought about by Darwin's theory.

I will try to show in this article that exactly the same principles are the active leaders of business, under which term I comprise both commerce and industry. Before discussing modern business we will in a few words consider the origin of this part of human activity.

Karl von den Steinen, the eminent ethnologist, has published some very interesting information regarding the business of the primitive nations of Brazil. According to his data the first tools are nothing else than imitations and variations of the tools contained in the human and animal body, first of all of the teeth. Later on these

tools are more or less adapted to a working purpose. But there is no doubt that the teeth and bones of animals are the starting points of the industry. At a later stage the principle of imitation is put to use by shaping the forms of the natural tools from other materials; variation for a certain purpose is the next stage; the principle of adaptation becomes evident in the fact, that in the beginning every nation has to get along with the materials obtainable in their natural surroundings.

Only after some time has elapsed, the barter or exchange is developed which helps to remove more or less the limitation of local conditions. This manner of trade has at first the character of gifts which are given to one's host, which circumstance might well create the idea that formerly trade was more a matter of sentiment than it is to-day. However, this is wrong, as is seen from Karl von den Steinen's description. He relates that the Brazilian aborigines very ingenuously send away a visitor who would sojourn with them for a long time without paying some kind of retribution. This shows that these presents are by no means of small importance, and that even with these Indians we cannot find a trace of a golden age. And it is quite natural that a man who has needs—which constitute one of mankind's essential characteristics—expects a solvent "business-friend" to repay or re-render a service which has been done to him. This cannot be called avidity, but is only the expression of the desire to render one's life more stable and secure, and to obtain more enjoyment and a longer durance of life. Even the most primitive tribes are not generous in respect to what is later called financial matters, and the savage always expects something for something.

These preliminary remarks prove that industry and trade, buying and selling, are most natural and in their first stages are exercised in a rather naïve fashion; and the naïveté is not at all the effect of intensive kindness and nobleness but only of the crude, undeveloped and primitive way of thinking. (Little children show like properties: a girl of six will certainly be generous enough to give away the much-hated piano but will hardly be ready to do the same with her doll. She would, for the latter, demand something that she considers equivalent.)

We shall now consider modern business and show, by means of a number of examples, how the principles of adaptation, comparison, variation and preformation of possible future effects in thought are

applied in practical business. We will discuss trade and industry separately, as far as this is possible, and begin with an example derived from trade.

Suppose a large American firm manufacturing machinery, dry goods, paper or soap, etc., desires to increase its business by the addition of an export department. In order to accomplish this end, an experienced firm naturally will not start by sending a salesman to Mexico, Brazil, India, etc., with goods appealing to American taste and being packed in American manner, as it is practically known and also theoretically explainable, that an undertaking thus started is a failure in most cases. The business man knows that only by a very rare chance could the style and packing of American goods suit the foreigners. He also knows that this enterprise involves a process of adaptation which naturally has to be carried out as economically as possible, because every firm's financial means are more or less limited. Since it is a waste of time and money to wait until the foreigner is adapted and accustomed to the American style of goods in American packing, the great business man will always start his export trade by shipping his goods in the style and packing used in the country of destination. He will obtain the information necessary for this purpose through some business friends or through a man whom he sends out to investigate the possibilities of a new market. Even in the selection of this traveling man the principle of adaptation is considered. One will naturally select a man perfectly familiar with the language of the respective country and, if possible, a man who has lived in that country for years and is therefore thoroughly versed with the requirements of the market. It would be uneconomical if one had to wait until this man learns the language and the particular conditions of the foreign country and even more uneconomical if one would wait until the prospective customers learn the language of the American salesman, so that they can buy his goods. Even after the business is started the principles of adaptation and variation regarding climatic and social conditions must not be lost sight of. The shape and packing of the goods have to be adapted to the moisture of the atmosphere, the time of storage and the manner of consumption, *i. e.*, whether a package is used up all at once or in several portions. When exporting to high mountainous regions which are only accessible by mule transport the cases must be of such size that a mule can carry one or two of them. This is the reason why machines destined for

mines and works located in the high mountains of Mexico or South America are shipped in parts ready for mule transport. An example of the adaptation to the moisture is the sale of caustic soda for domestic soap manufacture on a small scale which is still carried out in a good many farm houses. A chemical firm manufactures, for this purpose, small balls of caustic soda dipped in molten rosin. The thin coating of this material successfully prevents the action of moisture. Variations have to be frequently performed so as to suit the atmospheric pressure; for instance, in gas engines. The sucking power of these machines naturally decreases in high altitudes if the *weight* of the air and gas drawn in are considered. Hence, a gas engine to be used in the high mountains must have a higher "standard" capacity than an engine used at low altitude in order to perform the same work. When starting a trade with new products, all such "energetic" circumstances have to be carefully considered. A dye may be sunproof upon the evening dress of a lady for a few winter receptions, but will be quickly bleached upon the fez of a longshoreman in Bahia or upon the shawl of an Italian peasant woman. Many European goods are deteriorated by the moisture of the American climate.

The principle of comparison is always and generally applied in trade, especially in figuring the cost of transportation. Here, in most cases, the time required for the transportation must be taken into consideration so that with a limited time of delivery necessarily the quickest, *i. e.,* the most expensive, way of transportation has to be used. If the time of delivery is sufficiently long, the cheapest possible way will be selected. Depending upon the freight rates, it will be decided in every case what route has to be used and whether the goods have to be shipped by rail or boat. These questions are frequently of rather complicated nature, and can be answered in a competent manner only after much practical experience.

, Before starting an innovation the business man experiments in thoughts exactly as does the scientist. He tries to adapt his thoughts to the facts, and endeavors to bring these thoughts into harmony. In his mind, he changes the circumstances and tries to predetermine the consequences of these changes. The capability of correctly predetermining these changes is the essence of the able, far-sighted, genial business man;; on the other hand, the formation of a superficial judgment is characteristic of the unable and uneducated business man. I will illustrate this by an example: it is

well known that the consumption of denatured alcohol in Germany for thousands of small applications is very large. The main uses are for boiling, heating and illuminating. What facts would an American business man have to consider if, tempted by the German success, he would feel like introducing into America on a large scale the application of denatured alcohol and of the appliances used in connection with it? Since a few years denatured alcohol is very cheap in this country, though still somewhat more expensive than in Germany. In the first moment our business man will think of the immense agricultural areas of America, of its productivity in grain, of the American skill in machine construction, by means of which the appliances for manufacturing alcohol would certainly be largely improved, so that the price of alcohol would surely fall below the German level within a short time. He will remember some newspaper articles in which it was stated that alcohol can be manufactured from sawdust— which can be had in America in unlimited quantities—and now he will be fairly certain that in time the price of American alcohol will be much lower than of the German material. All these points will seem encouraging to him in his investigation regarding a possible success of alcohol appliances, and if he is unable, he will not study nor consider the differences between German and American conditions and will, misled by German success, invest his moderate fortune in this enterprise. Only after the loss of his capital will he know the detailed circumstances relating to this business. He pays with his money for his entire inability to preform the future in his thought and imagination.

The able business man, on the other hand, will have a better view of the situation *before* he starts an enterprise than the unable man after losing his capital. The able man will learn that the German alcohol industry and the use of the appliances connected with it have grown up slowly, and that also in America it will take many years until this industry and the various applications get over their infant diseases. He will thoroughly look around and find that a profitable production of alcohol from sawdust cannot be expected for many years; that the German alcohol is almost entirely made of potatoes; that American potato culture will hardly ever be so large as to furnish sufficient raw material for a big alcohol industry; that the present raw materials furnished by American agriculture will always keep the price of American alcohol above the German level; and that therefore the present price of alcohol will not be considerably

decreased, so that by reason of this higher price, the use of alcohol in America will hardly ever approach the quantities consumed in Europe.

Furthermore, the able man will consider some other facts; he will learn in what respect the present time differs from the time of the industrial introduction of alcohol in Germany. The successful introduction in Europe took place at a time when most of the houses had no city gas connection (for illuminating and rapidly boiling and heating), nor electric connection, so that the advent of alcohol was welcomed as the only means permitting boiling and cooking without a coal fire. The coal fire was the only competition to be overcome, so that the alcohol was readily accepted for all uses, in which convenience is an item. In the America of the present time however, alcohol will meet more powerful competitors, which are more convenient and if any only slightly more expensive—gas and electricity. The able man will see that for domestic use in towns of over 2,000 inhabitants the alcohol comes too late, as almost every one of these towns possesses a gas or electric plant, and that even in the lonesome farmhouse and summer hotel it has to fight and to displace excellent kerosene stoves and lamps or satisfactory acetylene plants. The real business man will now understand that the alcohol and alcohol appliance business can be made a success by the investment of large capital, much time and hard work only.

Such preconstruction in thought is paramount for the result and success of a business in all similar cases. The genial business man knows exactly how far his capital will reach, while, for instance, an excellent mining engineer who has no business ability may take out a number of the very best mining claims, and may think that he can work them with his insufficient capital, until, finally, he has to give up. He was simply unable to preconstruct actual conditions in thought; he has forgotten altogether that the gold is without any value as long as it is in the bowels of the earth and that a certain minimum of capital is necessary to get the metal to the surface.

Most business failures can be explained by a defect or fault in the construction of the "thought-image"; in one case the cost of transportation, in another the cost of labor, in a third the market of the raw materials and in a fourth the unexpected "manufacturing difficulties" have not at all or only insufficiently been considered.

"Chance and accidental circumstances" are in business just as important as in science. It was accident when Roentgen made his

great discovery; but this same accident would not have led to the discovery in the hands of an average physicist. Roentgen's power of observation was necessary in order to utilize the accident. The great business man works in the same manner. The able president of a steamship company will immediately start a new line to and from South Africa, as soon as he hears that the gold craze out there is assuming extraordinary dimensions, which necessarily has an increasing effect upon the transportation business. If a great railroad man finds out that a few hundred miles from his line oil has been found in large quantities he will start the construction of a branch line in order to get hold of the oil transport. If the conditions are favorable he will even provide his locomotives with oil firing.

The application and utilization of these principles is clearly evident in the organization and operation of the trusts. In this case control has to be obtained not only of the manufacture of a certain product, but frequently also of the raw materials necessary for the manufacture of a more or less finished material. The organizer of a trust combines under one central administration, *i. e.*, he centralizes those factories of a kind which are best equipped and most advantageously located.

The administration of these large industrial combinations is based upon an extremely elaborated filing system. In various ways the relation of the individual plants to each other and also of the various parts and stages of the manufacturing process to each other is ascertained.

The supervision of such a large organization is made possible only by daily, monthly and yearly reports prepared along these lines. For instance, in a zinc smelter daily reports have to be made of the reduction coal consumed in every furnace block per ton of ore of a certain zinc content and per ton of metal obtained, of the number of retorts broken per ton of charge and per ton of yield, of the amount of coal burned in the producer, of the quantity of coal burned per roasting batch etc. In the manufacture of zinc oxide from willemite and similar ores, besides the relations of the materials consumed and obtained, also the grate area of the oxide furnace has to be considered in the reports. It has to be stated how much of every material entering the manufacturing process is used per unit of grate area, and how much oxide is obtained. On the other hand also reports will have to be made in which the items of the process are referred to the weight units of ore or oxide. By

viewing in such a manner a certain field from many sides and points of views, a large amount of useful and necessary information is obtained in an accessible form which can be read and understood by everybody connected with this business. The use of these reports is facilitated by filing in the main office two copies of each, one with the file of the factory to which it refers, the other according to the date.

The application of the principles of science is also evident in the adaptation of the production to the demand, in the variation of the manufacturing processes according to new conditions, in the principle of comparison which is generally used, in the utilization of accidental circumstances, and in the decision whether it is of economic advantage to start a new industry. The "thought-experiment" is important in the solution of all these questions.

When the quality of the raw material which is at disposal is changing, a corresponding change has to be made in the process of manufacture. If the latter gets unprofitable through a rise in wages, automatic appliances will have to be introduced as far as possible; if the increase in the price of raw materials makes an industry unprofitable, the yields will have to be increased by all possible scientific means and the by-products will have to be utilized.

In all these problems the clever execution of the thought-experiment and the consideration of all the main and minor facts, circumstances and conditions is of the greatest importance. Depending upon the complicateness of the case, the establishing and defining of the problem and the solution of the problem is of varying difficulty. For instance, if the price of bleaching powder drops, other more profitable utilizations of the chlorine have to be found in electrolytic plants manufacturing caustic soda, as per example, the production of hydrochloric acid by passing a suitable mixture of steam and chlorine through incandescent coke. Only after careful experiments on a small scale and after consideration of all manufacturing items should the installation of a larger plant be undertaken. Even at Niagara Falls the consumption of power has to be calculated; in fact, several industries at Niagara Falls were ruined by the expenses for power generation (utilization of the nitrogen of the atmosphere; production of barium oxide from heavy spar). Local and individual conditions always have to be carefully considered. In factories where the entire exhaust of the steam engine can be utilized for heating purposes, the use of gas engines and producers would

be out of place though in nearly all other cases a considerable saving is effected by these appliances.

In starting a new industry, great care must be taken, as was already shown above, in the discussion of the utilization of alcohol. It is by no means sufficient to know that a certain industry is booming under entirely different conditions; the boom in one country is no reason for the boom in another country. The American coal-tar color industry, for instance, will have to overcome many difficulties in the future because of lack of skilled American labor and also of chemists, while, on the other hand, Europe is accumulating an increasing stock of workingmen and chemists skilled in these industries, so they probably will be always ahead of America. If anybody who should intend to introduce in America certain artificial stone industries which are successful in Europe (magnesia cement, xylolith, etc.) he will not feel very much encouraged if he learns of the large number of artificial stones on the American market; through further investigation he will find that all the raw materials for these industries have to be imported, that this can be profitably done only by cargoes, and that therefore a larger capital is required for this enterprise, and that more competition will have to be met than a superficial investigation would indicate.

With a new chemical process, the thought-experiment has to be made in other directions, as the following example will show. If a very large and very expensive installation for the manufacture of synthetic camphor is to be established, the estimation of the future profit should not be based upon the present market price; one will have to keep in mind that the production of camphor is a monopoly of the Japanese government, that to-day the market price is kept at an artificial height, but that, on the other hand, Japan possesses immense reserve forests of camphor trees whereby she is in a position to let the market price drop to any point if she desires to crush her competitors. If now instead of a very expensive installation for the manufacture of synthetic camphor a considerably cheaper plant can be established for the manufacture of a material nearly though not entirely identical with Japanese camphor, this will be undoubtedly preferable.

The refining of cocoanut fat, which is a considerable industry in Europe, furnishes also an interesting example. We can import cocoanuts to America as cheap as they can to Europe. Where lies the difference between the conditions? Why were all the American

experiments for establishing such an industry unsuccessful? Because there is no need for such a fat in America, as this country produces a sufficient quantity of animal and vegetable fats, which are prepared by simpler and more convenient processes than the refining of cocoanut fat.

If such a thought experiment results in the positive decision to start a certain industry, a new thought experiment has to be started directly regarding the location of the factory. Herein the main points to be considered are labor, fuel, raw materials, market and the question of transportation.

If systematic improvements or inventions are to be worked out in an industry, the principles of science are also followed. One utilizes the experience and experiments made in the same direction by unsuccessful or not quite successful predecessors; one tries to explain the reason of their failure and to remove from the experiments to be undertaken the circumstances causing the failure of former experimenters. An example: if I am about to work out a process for making zinc in a blast or shaft furnace I learn from the history of metallurgy that all previous experiments along these lines were made by means of producer gas, etc., *i. e.,* always in the presence of some oxygen and of considerable quantities of nitrogen. All these experiments were actually a failure and the product obtained by these processes was, instead of metallic zinc, a mixture of zinc dust and oxide. I therefore try to explain the "cause" of the formation of this mixture; at last I believe to have found it in the diluting effect of the oxygen and nitrogen upon the atmosphere of the furnace. Now I experiment with and in my thoughts, until I see a way to eliminate these effects. I travel in my thoughts in the direction of producer gas; I try to find an economical process for eliminating the nitrogen, in order to then reduce the zinc oxide by means of highly heated carbon monoxide. Suddenly—under formation of a new series of thought based upon some experiences gained many years ago—the water gas comes into my mind. This gas without any further treatment possesses all the qualities of a suitable reducing substance. Finally, the result of the thought experiment has to be checked by a number of actual experiments.

Great care must be taken in judging a new situation, a new enterprise or a new invention. One must be ready to modify the results of previous observations, since an "absolute" confidence in the details of former experiences frequently prevents the appreciation

of new and valuable inventions. The relation of the phenomena to each other and their interdependence (cause and effect) should be earnestly studied. A small change in one condition or circumstance frequently means a considerable change in one or more other conditions or circumstances. A lack of brain education always gets evident in the solution of these questions, and errors as well as false conclusions are extremely frequent in this particular field of research work. We must, first of all, constantly keep in mind that neither the world, nor the sciences nor our experiences are as yet finished, and that an exaggerated confidence is an obstacle to progress, as the following example will show.

It is well known that the reduction of iron ore in the blast furnace is effected by blowing highly heated air taken directly from the atmosphere through the furnace containing a mixture of ore, coal and flux. This process is still in most general use, though it is known that the moisture of the atmosphere increases the coal consumption in the furnace. Up to a few years ago the removal of the moisture from the air or blast was not carried out on a large scale because the technical and chemical experience of the past tended to show and apparently proved that the saving effected by artificially drying the blast would undoubtedly not be any greater than the cost of drying. This supposition is proved by our present theories. But what, if the latter are too narrow and the former incorrect? Is it not possible that certain important conditions or relations were neglected or that the interdependence of certain phenomena was incorrectly "explained"? The fact is that all theorists were rather sceptical, when, a few years ago, the iron master Gayley published his process for drying the blast by freezing and when he explained that a saving of eight per cent. would be effected by this process in the manufacturing cost of pig iron, the most prominent German iron men expressed an opinion, which was by no means in favor of the process.

Shortly afterwards reports were published about a few successful plants of ths system, but the theorists still stuck to the opinions prescribed by their theory. They stated that—if this process would really be a success—they would have observed in their own works a difference between summer and winter yield, as in winter the blast is subjected to a natural drying and freezing process. However, they had not noticed any difference in the yields. So they asked for actual figures and in this they were perfectly right. To-day these

figures are at hand, from a number of successful American plants and Gayley was correct in his assertions, though as yet, his success cannot be explained theoretically (most probably a change of the chemical equilibrium is effected in the blast furnace). Hence the theorists had, in this affair, more confidence in their theories as was proper and practical. At the same time, we see that the thought experiment in the head and on the paper has effective value only if it is afterwards tested by an actual, material experiment. Otherwise, we run the risk to get everything simply from the depth of our minds and to consider it as actual.

We will now investigate the problem of a new source of light. Here also we must keep in mind that it is dangerous to unduly generalize and to exaggerate our old experiences. Our eye being adapted, in a certain degree, to the sunlight, one may easily arrive at the conclusion that an artificial light will be the healthier the more similar it is to sunlight. We may think, for instance, that a light which contains almost exclusively green and blue rays will be harmful or at least tiresome to the human eye. A confirmation of this supposition may be found in the fact that an electric incandescent light is more pleasing to the eye than an open gas flame. Notwithstanding all this, the assumption that the optic quality of a light increases with its greater similarity to sunlight, is absolutely wrong. For, experience has shown that the Cooper-Hewitt light, which I had in mind when mentioning above a light composed of green and blue rays, is more agreeable to the eye (at least of typesetters, printers and machinists; obvious reasons prevent its use in places, where colors have to be distinguished) even for continuous work, than any other artificial illumination, though every one of the latter is nearer to the sunlight, as far as the composition is concerned, than the Cooper-Hewitt light. The points herein to be considered are therefore different from the points generally considered by "common sense" people.

Hence the same principles are valid both in science and in business. In each of the two fields every new idea has to take up the fight with prejudice and tradition. I just mention the fight of the trusts, which are exactly like the fight of a new scientific theory with the old tradition. In both it takes much time and hard work until the foundations are solidly built and the superstructure firmly established.

Finally I want to mention the most obvious and most familiar similarity between science and business, namely the economic character of both. It is the aim of the scientist to conquer with the least possible expense of brain work as much as possible of the unlimited field of truth; it is the aim of the business man to effect the production of values by the least possible expense of labor.

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